Commonwealth of Pennsylvania
Department of Public Instruction

Courses of Study in Science for Senior High Schools

Biology
Physics
Chemistry

Physiology, hygiene, narcotics, alcohol

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Foreword

IN a paper published in 1749, Benjamin Franklin proposed that pupils were to read Natural History and were to practice "a little gardening, planting, grafting, inoculation, etc.;" and "now and then excursions made to the neighboring plantations of the best farmers, their methods observ'd and reason'd upon for the information of youth." Science teaching very early was recognized as an important phase of the educational program of the Commonwealth.

In realizing the objectives of secondary education science has much to offer. It helps to furnish the basis for rational and scientific living and thinking. Today we are called upon to make decisions, to evaluate, and to judge products, materials and situations where both scientific facts and procedures are needed. In addition, life is made more worth living when scientific attitudes and appreciations aid the individual in interpreting things about him.

Pennsylvania's program of public education is designed to provide continuous contact with science from the kindergarten through grade nine for all pupils, and to give electives courses in grades 10-11-12 which will continue the work of the first nine grades and provide the work essential for expanding the vision of the pupil, show him the part played by science in human welfare, create a love for truth, correct false impressions, develop scientific habits and procedures, and give practice in independent thinking and the application of scientific data and procedures in the solution of personal and public problems.

During the school year 1930-31 the following was the enrollment in the senior high school years (grades 10-11-12):

	Grade 10	*Grade 11*	*Grade 12*	*Total*
Biology	48,681	1,385	810	50,876
Botany	3,447	602	234	4,283
Chemistry	543	15,186	13,106	28,835
General Science	3,353	299	179	3,831
Geology	......	159	182	341
Physics	957	14,755	9,937	25,649
Zoology	2,216	136	195	2,547
Total in Science	59,197	32,522	24,643	116,362
Total Enrollment	88,565	65,220	51,770	205,555
Percent in Science	66.8	49.8	47.6	56.9

Compared with the total enrollments in the senior high school grades, 66.8 percent of tenth year pupils were enrolled in science courses, 49.8 percent of the eleventh year pupils and 47.6 percent of twelfth year pupils.

This course of study for senior high school which has been developed by cooperative committees provides for Biology in the tenth year and Physics and Chemistry in grades eleven and twelve.

The membership of these committees follows:

BIOLOGY

EDWARD E. WILDMAN, Chairman
Director, Division of Science Education
Board of Public Education, Philadelphia

JAMES S. GRIM
State Teachers College, Kutztown

ELMIRA LODOR
William Penn Senior High School, Philadelphia

DOROTHY M. SCHMUCKER
State Teachers College, West Chester

ELMER B. ULRICH
Simon Gratz Senior High School, Philadelphia

PHYSICS

EDWARD E. WILDMAN, Chairman
Director, Division of Science Education
Board of Public Education, Philadelphia

JOSEPH M. JAMESON
Girard College, Philadelphia

ARTHUR W. LOWE
Frankford Senior High School, Philadelphia

LAURA A. REANEY
Chester High School, Chester

THEODORE S. ROWLAND
Northeast Senior High School, Philadelphia

DENA UNGEMACH
Kensington Senior High School, Philadelphia

CHEMISTRY

DAVID B. PUGH, Chairman
Pennsylvania State College, State College

ALFRED W. BEATTIE
Ben Avon High School, Ben Avon

DAVID W. RIAL
Frick Training School, Pittsburgh

To these committees we acknowledge our indebtedness. To the teachers who aided in the evaluation of this material in its preliminary form and whose suggestions have been incorporated in the present course we also wish to express our appreciation.

Under the direction of Dr. Chester A. Buckner, Professor of Secondary Education, University of Pittsburgh, type units were prepared by each of the following: Walter G. Patterson, Principal of Senior High School, Donora, in Biology; Gale R. Kerschner, Scott High School, North Braddock, and Mr. Lambert E. Broad, Aliquippa, in Physics; and Miss E. Helen Sponcler, Beaver Falls High School, Beaver Falls, in Chemistry. Because of the necessity for limiting the size of the course of study it was found impossible to include these units with the present material.

These materials are part of a general program of curriculum revision organized under the direction of William H. Bristow, Deputy Superintendent, Curriculum Bureau, Department of Public Instruction. It is hoped that this Bulletin may be the beginning of a program of continuous revision. To that end we are requesting that teachers, principals and superintendents furnish the Curriculum Bureau with any suggestions which they may have, including units of work, tests and supplementary material used in connection with science courses. The experience of these teachers will form the basis for future revisions of this course and for issuing supplementary suggestions and materials.

JAMES N. RULE
Superintendent of Public Instruction

April 1, 1932

Course of Study in Biology

Introduction

According to the Report of the Commission on the Reorganization of Science in Secondary Schools, appointed by the National Education Association, biology for high school students should include a knowledge of

1. The way living things maintain themselves and their species.
2. The interrelations between organisms and groups of organisms.
3. The dependence of living things on the physical world about them.
4. The power of man to control the habits and relationships of plants and animals to serve his own needs.

The subject matter implied in the general objectives noted above has been arranged in this outline in five major units.

UNIT I. To appreciate the fact that all living organisms have essentially the same needs and consequently that they possess certain structural and functional characteristics in common.

UNIT II. To learn how plants carry on the activities of living things so as to maintain themselves. As an outcome of this knowledge there should be developed an appreciation of the beauty and usefulness of plants and a desire to aid actively in their growth and conservation.

UNIT III. To learn how animals carry on the activities of living things so as to maintain themselves. Associated with this outcome there should be aroused a desire to create and maintain sanctuaries for wild life and an appreciation of the beauty and usefulness of animals.

UNIT IV. To learn how generations of living things reproduce themselves. In this connection there should be aroused an interest in the facts and theories in regard to heredity, and their practical application in the work of the plant and animal breeders. In addition there should be developed an appreciation of the possibility and importance of the control and improvement of the human race.

UNIT V. To understand the interrelationships among living things and between living things and their environment. There should be developed an appreciation of the important part played by environmental factors in the life of all plants and animals including man, and a realization of human responsibility in environmental control.

Procedure

While the order of the units as given is a logical one from the standpoint of development, nevertheless it is not obligatory. With some slight changes the sequence of topics and units may be altered to suit local needs and differences.

It is suggested that the following sequence of units makes possible the use of fresh plant material when it is most easily available:

Classes beginning biology in September—

First Semester	*Second Semester*
Unit I	Unit IV or V
Unit II	Unit V or IV
Unit III	

Classes beginning biology in February—

First Semester	*Second Semester*
Unit I	Unit IV or V
Unit II	Unit V or IV
Unit III	

It is designed that each of these major goals shall be reached by means of a number of specified objectives, each of which is to be attained by one or more activities to be carried out by individual students or by the class. These "suggested activities" involve laboratory work, textbook and other reference study, and visits to forest, park, garden, field, pond and stream, and to local industrial plants as well as to museums.

Specific directions can not be given to the teacher as to just how each "suggested activity" can be best carried out. This must be left to the judgment and initiative of the teacher. But it is expected that every "specific objective" shall be regarded as a problem to be solved according to the scientific method,—that is, from the impartial observation of first-hand data in the laboratory, field, or museum, not merely by reading the findings of others in text or reference books. Herein lies the essential difference between a lesson in science and one in history. This outline is not to be regarded as an outline of a course in the history of biology. It calls therefore, for careful fore-thought and planning on the part of the teacher.

Teacher-Pupil Demonstration and Individual Laboratory Work

While it is impossible, because of the great variation in facilities, to make any definite statement as to what is the correct proportion of individual laboratory work which should be done by the pupils and of demonstration by the teacher or by the pupils, there are certain guiding principles which may help each teacher to decide for himself which methods he will follow in each lesson.

Investigation has shown that, for certain types of lessons, better results in acquisition of scientific facts are secured by teacher-demonstration than by individual student experiment (the student frequently losing sight of the fact or principle which he is seeking because his interest is centered wholly upon the performance) ; that much time is wasted by the individual method, and that much needless expense is incurred by the necessity for having equipment in much greater quantity and by the more frequent breakage.

Against these disadvantages of the individual method there are however, certain very marked advantages, so great that they outweigh the disadvantages in many cases. One of these is the development, to greater or less degree, of skill in handling materials and apparatus; in making selection of materials for the experiment or observation, and in assembling these materials for the designed purpose.

Individual experimentation is also desirable where very close observation is necessary. Some laboratory work lends itself well to group participation, which has its educational value.

There is no doubt that each of the above methods has its worth and that each should be used at times during the course. It is suggested that the teacher consciously measure the results secured along the following lines to decide, for his own future use, the value of each method in his classes.

1. Does the pupil learn the facts necessary to answer the specific problem he seeks to solve?
2. Does the pupil remember these facts?
3. Does the pupil develop skill in handling materials?
4. Does the pupil develop cooperation?
5. Does the pupil develop initiative?
6. Does the pupil develop leadership?
7. Does the pupil develop the scientific habit of seeking cause and effect and of forming just conclusions?

The Note-Book

The note-book is essential as a means to an end. It should contain accurate records of what the pupil has seen or heard. The record in the form of drawings or descriptions should be made at the time of the observation. While neatness and artistic execution are desirable the essential points are accurate observation and reasonable interpretations. Drawings, though not specifically mentioned, are presupposed throughout the course.

Much of the note-book should consist of records of experiments. For each of these it will be helpful to use a definite form, consisting of a statement of:

1. Problem
2. Operation of procedure
3. Observations
4. Conclusions
5. Development

Organization

This outline is not intended to cover the entire field of biology nor is it suggested that all of the units are to be taught with equal emphasis. It is proposed as a guiding outline. No time allotment is assigned to the several units. While the entire outline should be covered within the year the amount of time spent on any part of it should be determined by the teacher's initiative and the ability of the pupils. The work is not organized to meet college entrance requirements, nor is it merely an outline for nature study. A high standard of biological training on the secondary school level, fitted more to the present than to the future needs of mid-adolescents should be held constantly in mind.

Equipment and Supplies

The following materials should be available for use by students and teacher.

Aquarium, square, round and bowl types	Acid hydrochloric
Boxes, slide	Alcohol, ethyl
Breeding cages	Balsam, Canada
Charts, blank	Beakers, Pyrex
Charts, botanical	Crayons, wax
Charts, zoological	Dishes, crystallizing
Cover glasses	Dishes, Petri
Forceps, dissecting	Eosin
Jars, battery	Ether
Jars, bell, low and high forms	Fehling's Solution
Lantern, projecting	Formaldehyde
Lantern slides	Funnel
Magnifiers	Iodine solution
Microscope, dissecting and compound	Lime water
Microtome, hand	Maps, outline
Model, Anatomical (various animals and plants)	Poster paints

Mount, Protected Specimen, Riker's (specify size)
Needles, dissecting (wooden handle)
Razor, sectioning
Scalpels
Skeletons (various animals)
Slides, micro
Slides, micro, prepared
Pots, flower, various sizes
Seeds, beans, peas, wheat, corn, sunflower
Sphagnum
Stains, such as aniline green, safranine
Tubes, funnel, thistle top
Tubes, test
Tubing, glass
Vials, specimen, various sizes
Watch crystal
Watch glass, Syracuse
Xylol

A Few Good Text and Reference Books—This List Could be Greatly Enlarged

Text and Reference Books	*Published by*
Allee—Nature of the World and of Man	Chicago Univ. Press, Chicago Univ., Chicago, Ill.
Altenberg—How We Inherit	Henry Holt & Co., New York City
Apgar—Trees of Northern United States	American Book Co., New York City
Conn—Bacteria, Yeast and Molds	Ginn & Co., New York City
DeKruif—Microbe Hunters	Harcourt, Brace & Co., New York City
Duggar—Fungus Diseases of Plants	Ginn & Co., New York City
East—Heredity and Human Affairs	Chas. Scribner's Sons, New York City
Geddes, Thompson—Biology	Henry Holt & Co., New York City
Gruenberg—Elementary Biology	Ginn & Co., New York City
Holmes—Introduction to General Biology	Harcourt, Brace & Co., New York City
Howard—Insect Book	Doubleday-Doran Co., Garden City, N. Y.
Hunter—New Civic Biology	American Book Co., New York City
Hunter—New Essentials of Biology Presented in Problems	American Book Co., New York City
Illick—Pennsylvania Trees	Department of Forests and Waters, Harrisburg, Pennsylvania
Kinsey—Introduction to Biology	J. B. Lippincott Co., Philadelphia
Linville—Biology of Man and Other Organisms	Harcourt, Brace & Co., New York City
Moon—Biology for Beginners; rev. ed.	Henry Holt & Co., New York City
Peabody and Hunt—Biology and Human Welfare	The Macmillan Co., New York City
Pearl—Rate of Living	Knopf Pub. Co., 730 5th Ave., New York City
Rogers—The Tree Book	Doubleday-Doran Co., Garden City, N. Y.
Sargent—Plants and Their Uses	Henry Holt & Co., New York City
Stiles—Human Physiology	Saunders Publ. Co., Washington Sq., Philadelphia
Thomson—Everyday Biology	Doubleday-Doran Co., Garden City, N. Y.
Trafton—Biology of Home and Community	The Macmillan Co., New York City
Waldon—Economic Biology	McGraw-Hill Book Co., 370 7th Ave., New York City

A Few Good Reference Books for the Teacher—This List Could Also be Greatly Enlarged

Reference Books	*Published By*
Bigelow—Teaching of Biology	The Macmillan Co., New York City.
Brownwell & Wade—The Teaching of Science and the Science Teacher	Century Pub. Co., 353 4th Ave., New York City.
Finley—Biology in Secondary Schools and the Training of Biology Teachers	Teachers College, Columbia Univ., New York City.
Locy—Biology and Its Makers, 3rd ed.	Henry Holt & Co., New York City.
Sinnott—Principles of Genetics	McGraw-Hill Book Co., New York City.
Woodruff—Foundations of Biology	The Macmillan Co., New York City.

Pennsylvania State Publications

Teachers of biology throughout the state should be acquainted with the work of several of our state administrative departments and commissions, with offices as Harrisburg. Their students will probably find the work of the following to be of the greatest interest.

1. The Department of Forests and Waters.
2. The Department of Agriculture, including work of the Plant Pathologist and the State Botanist.
3. The Department of Internal Affairs, State Geologist.
4. The Department of Labor and Industry.
5. The Department of Public Instruction, Division of Visual Education.
6. The Department of Welfare.
7. The State Game Commission.
8. The State Fish Commission.
9. The State Museum.
10. Though not an official organization the Pennsylvania Forestry Association* has been of great public service, and its journal, *Forest Leaves,* is of value. U. S. Government publications, especially those of the Department of Agriculture are also valuable.

*C. P. Birkinbine, Sec'y, 714 Commercial Trust Bldg., Philadelphia, Pa.

Unit I

General Characteristics of Living Things

This topic or unit is to be considered merely as introductory to the special topics to follow. The time allotment therefore should be brief. The suggested activities should be carried out with no detail. Full use should be made of the previous observations and knowledge of the pupils.

If there is objection to introducing the use of the compound microscope in this topic, a micro projector may be employed instead.

This work is not to be interpreted as involving a detailed study of cell structure. Only the main points are to be observed and emphasized.

The Specific Objectives for this Unit are:—

A. To discover how living and non-living things differ.
B. To discover that special activities are carried on by all living things.
C. To discover what is meant by protoplasm and to learn its properties.
D. To learn that living things are constructed of cells.

Specific Objectives (1) and Desirable Outcomes (2)	Content and Suggested Activities
A. To discover how living and non-living things differ. *A realization of the activity as displayed by living things in contrast to the inertia of those which are not living.*	Comparison of living and non-living things. Living material in the laboratory as well as information from the personal experience of each student outside of school should furnish the basis of this comparison, e. g., comparison of ore, rock, mineral deposits with living plants and animals; comparison of shells of snails, clams, oysters, etc. with living insects; comparison of effect of light on growing plant in flower pot and the effect of light on the flower pot itself.
B. To discover what special activities are carried on by all living things. *A recognition of the fundamental needs of all living organisms. This should be summarized in outline form.*	Observe behavior of living things in the laboratory, supplemented with reports of observations of plants and animals outside of school. List the general activities carried on by all living things.
C. To discover what is meant by protoplasm and to study its properties. *A realization that all of the activities of living things are the result of activities of protoplasm and that therefore protoplasm is the physiological basis of life.*	Observe egg albumen, study the physical appearance as illustrative in general of the appearance of protoplasm. Observe living protozoa and spirogyra using microscope to get a general idea of protoplasm. Discuss the universal presence of protoplasm in all living things.
D. To learn that living things are constructed of cells. *An idea of the arrangement of protoplasm in the form of cells and that these cells vary greatly in form, size, and function.* *A realization that the protoplasm cell is the unit out of which all living things are built.*	Examine algae from bark on north side of trees (microscope slides). Examine mounts of yeast, amoeba, paramecium, root hairs, sections of leaves, stems, animal tissues, etc. Direct attention to the general, more obvious structural characteristics which all cells have in common. Direct attention to differences. Reports by students of work of Schleiden Schwann.

(1) **Specific objects printed in bold face;**
(2) *Desirable Outcomes printed in italics.*

Unit II

How Plants Maintain Themselves

Throughout all of the lessons devoted to this unit, constant use should be made of fresh material. The laboratory should be kept supplied with living plants, and garden and wild flowers in their seasons. The students should be trained in the cutting and collecting of these flowers and in the care of the laboratory plants. Field trips should be an integral part of the work and much use should be made of supplementary illustrative material, e. g., charts pictures, lantern slides, films. The students should become familiar with the flora of their own neighborhood and their interest and curiosity should be aroused in regard to the plant life of other regions. There should be stimulated by this topic not merely a passive understanding of some of the facts connected with plant biology, but also an active part in the growing and cultivating of plants.

The Specific Objectives for this unit are:—

A. To consider the activities carried on by all plants.

B. To study the work of the specialized parts of a plant concerned with its maintenance.

- 1. Activities of roots
  - a. Anchorage
  - b. Responses to stimulation
  - c. Nutrition | need for food | source of food | study of soil
  - d. Modifications
- 2. Activities of stems
  - a. Support
  - b. Transportation
  - c. Modifications
- 3. Activities of leaves
  - a. External structure
  - b. Work of leaves
    - 1. photosynthesis
    - 2. respiration
    - 3. transpiration
  - c. Internal structure
  - d. Modifications

C. To discover how plants are essential to the life of animals and man.

- a. Plants supply oxygen needed in respiration
- b. Plants supply food needed by animals and man
- c. Plants supply shelter
- d. Plants supply clothing for man
- e. Plants supply fuel
- f. Plants supply tools

D. Classification of plants

- a. Increase in complexity
- b. Basis of classification
  - 1. General characteristics of phylo

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
A. To consider the activities carried on by all plants in order to maintain themselves. *A renewed realization of the inherent activity of living protoplasm.*	Review **BRIEFLY** the activities of plants as observed by the pupils outside of school and in the lessons of Unit I.
B. A knowledge of the parts of a plant which are concerned with the carrying on of its essential activities. *The general outcome of the work of the second topic in all of its subdivisions is to be an appreciation of the advantage of division of labor and a realization of the interdependence of the various activities on specialized functions in order to secure the survival of the plant as a whole.*	Recall from previous knowledge the names of the parts of a living plant. Discuss which of these parts are necessary for the life of the individual. By means of field trips, fresh material in the laboratory, pictures, lantern slides, etc. the students should gain not only an idea of the great variety of plants but also of their essential similarity.
1. To study the special ACTIVITIES of ROOTS a. Anchorage **(1) To discover that roots act as anchors for the plant.**	Try to pull growing plants from the pots or window boxes in the laboratory. Pupils report on "weeding," blasting out stumps of large trees, etc. From specimens in the laboratory and reports by pupils of their own observations on plants blown over by the wind or pulled up for any reason, discuss the various kinds of root systems.
(2) To study various types of anchorage systems. *A realization of the adaptation of root systems to their environment.*	Discuss the advantages of the various types of root systems as far as anchorage is concerned. Does the character of the soil and the presence or absence of water seem to have any bearing on the anchorage system developed by the plants? Do all plants have an anchorage system? What are aerial roots? What are epiphytes?
b. Responses to stimulation **(1) To study the response of roots to gravity.** *An understanding that roots are directly influenced by the physical forces of their environment.*	Germinate mustard, radish, or wheat seeds on moist paper. Attach some of the seedlings to cork in a horizontal position. Plant some seeds in the pores of a wet sponge. Suspend in a jar. Observe the behavior of the roots in these experiments with regard to direction of growth of roots.
(2) To consider the response of roots to light.	Devise an experiment which would illustrate the behavior of roots with regard to light. Discuss the relative importance of gravity and light as determinants of the direction of root growth.
(3) To study the response of roots to water. *A realization that roots are influenced by chemical factors as well as physical factors in their environment.*	Discuss the effect of the location of the water supply on the general positive geotropism of roots. Pupils report on the root systems of willows, water hemlocks, banyans, etc. Why is the Carolina poplar forbidden for street planting in many cities?
c. Nutrition **(1) To consider the need of plants for food.** **(a) The need for water.** *To realize that plants like animals are alive and need food.* *To realize that water is the medium by which plants obtain their food.*	Plant seedlings in dry soil—Do not water. Plant seedlings in moist soil—Keep well watered. Compare results. Pupils report on the watering of house and garden plants. Pupils report on the effect of drought on vegetation. Why are desert regions with scanty or no vegetation? Compare rainfall map of world with map showing distribution of vegetation. What is irrigation? Report on U. S. government irrigation projects.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
(b) The need for mineral salts.	Illustrate the effect of the solutions of mineral salts on seedling growth as follows:
To understand the nature of soil water.	(The seedlings should be well developed before the experiment.) Fill a series of flasks with the suggested solutions: 1. Distilled water. 2. Calcium sulphate. 3. Calcium phosphate. 4. Magnesium sulphate. 5. Sodium chloride. 6. Iron chloride. 7. Potassium nitrate. 8. A mixture of all the suggested nutrients. Support a seedling in the mouth of each flask so that the root is in contact with the solution. If possible carry out the experiment with seedlings of different plant families. Compare the rate of growth of the various seedlings. Observe the general physical characteristics of the seedlings. Are there any differences in addition to height differences?
(2) (a) The source of plant food. *To realize the extent to which man may govern the kind and supply of food needed by plants and hence his control of his own food supply.*	Plant beans, peas, or other seeds in pure sand. Plant beans, peas, or other seeds in garden soil. Compare growth. Evaporate to dryness water from as many different sources as possible. Heat soil of various kinds of dryness collecting moisture in bell jar or inverted beaker. Are all soils alike? This question may be answered by field trips and reports of pupils' observations on longer journeys. Why are all soils not alike? Review briefly rocks and soil making as studied in General Science. Explain why virgin soil produces larger crops. What is soil exhaustion? Why are crops rotated? What are fertilizers? Recall that rich valleys have been the homes of ancient civilization, and are still centers of population. Locate rich farming sections of this country. What relation do they bear to cities? To means of transportation? Is soil fertility the only factor which determines the location of population centers? Do all plants grow equally well in all soils? Reports on characteristic plants of a limestone region. Compare with vegetation of another rock formation. Pupils test soil for acid, and for alkali. What effects have roots on soil? Grow bean seedlings on blue litmus paper. Pupils report on the making and holding of soil by vegetation.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
(3) To discover how plants obtain their food from the soil. *To understand the probable explanation of absorption in all living protoplasm.*	Examine root hairs microscopically then with low power magnification. Show charts and diagrams of greater magnification. (Tradescantia grown in water produces an abundant supply of root hairs.) By means of an osmometer show how the process of absorption in plant and animal cells may be explained Illustrate how the soil water may enter the root hairs by comparing the process with the results obtained by the osmosis experiment. What is reverse osmosis? How might it be brought about?
a. To learn that some roots are adapted to special functions. *A realization of the adaptability of protoplasm to varying needs.*	Observe specimens or pictures of modified roots, e. g. storage, aerial, parasitic. Discuss each modification and its use in the general life of the plant. Examine roots of clover or vetch. Notice the tubercles. Discuss the need for nitrogen and the special work performed by the legumes. Discuss the specially modified roots which man has cultivated for his own use.
2. To study the special ACTIVITIES of STEMS. **a. To observe the external differences between stems and roots.** *A realization that differences in environment are accompanied by differences in external characteristics.*	Observe the external structure of several different kinds of common twigs. Examine the stems of the growing plants in the laboratory. Pupils report characteristics of tree trunks and branches. Note method of branching, bud arrangement, leaves or leaf scars, lenticals, cork. Compare with root. Does immediate environment account for differences?
b. To discover how stems respond to stimulation. *A continued realization that living things are responsive to physical and chemical factors of the environment.*	Review briefly the response of roots to the effect of gravity. light, water. Place a plant near a window. Do not turn. Observe result. Place a plant in a dark box so arranged that light is admitted from a single small opening. Observe result. Invert a box of growing seedlings. Observe result. Devise an experiment which would indicate whether or not water affects the position of growing stems. Recall from students' own observations the behavior of storm blown trees or other plants which have recovered their upright positions. Report the results of experiments with the clinostat and centrifuge on the position of roots and stems.
c. To study the special work of stems.	
(1) To observe that the stem is the supporting structure. *An added knowledge that specialization of function is accompanied by differentiation of structure.*	Observe the characteristic outline or framework of many different kinds of plants. Much use of illustrative material should be employed in this connection. The students should be encouraged to learn to recognize the winter as well as the summer aspect of the familiar trees and shrubs.
(2) To study the internal structure of stems.	Cut sections of stems with razor blade. Examine with magnifying glass. Examine stained and mounted sections with low power. Cut a ten year sapling into inch blocks. Examine these sections.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	Cut and examine longitudinal sections. Observe and study charts and models which show structure of different type stems. Identify parts. Compare pictures or sections of stems of various ages. Are these structures found in roots also? Use sections and models to demonstrate internal structure of roots. How can the approximate age of a cut tree be determined? What is the effect of drought on the annular rings?
(3) To discover the use of each part.	Discuss the use of the principal parts of a stem. Explain experiments which prove the uses of the several structures. Place twigs in eosin solution or red ink for twenty-four hours.
(4) To learn how sap ascends.	Place carrots or other roots in similar solution. Place a set of capillary tubes in the solution. Split the twigs and cut the carrot longitudinally. Trace the course of the red fluid. Discuss other forces that help to lift the sap, i. e., root pressure, evaporation from leaves. Explain sap flow in spring and fall.
(5) To learn where sap descends.	Girdle a small willow or poplar twig. Place in water with the water level below the girdle. Explain why roots form above the girdle outside the water. What harm may come from mutilating the bark of trees?
d. To learn that some stems are adapted to special functions.	From specimens and pictures study tubers, bulbs, tendrils, runners, cacti stems, and explain each special modification and its use to the plant.
e. To learn what man has done to control or modify stems for his own use. *An understanding of man's ability to control plant life for his own needs.*	Explain what is meant by grafting. Show specimen if possible. Examine specimens and pictures of the edible stems. Discuss the process of pruning, the making of "umbrella" and "weeping" trees, the stunting of trees for ornamental purposes, pleaching, etc.
3. Activities of leaves.	
a. To study the EXTERNAL characteristics of leaves. *A realization of the relation between the arrangement of leaves and the direction of the sun, hence the dependence of vegetation upon light.*	Examine the leaves of as many different plants as is possible. Note points of resemblance and difference. Examine a number of stems with the attached leaves. Note the arrangement of the leaves. Examine the plants in the laboratory with regard especially for leaf characteristics. Reports by pupils on shape, size, margin, veining, arrangement of leaves of house and garden plants and trees.
b. To discover the special WORK of leaves.	
(1) To find out the part played by leaves in the making of food. *An understanding of the importance of photosynthesis in the maintenance of life.*	Cover a part of a leaf of hydrangea or geranium with tinfoil. Hold covering in place with cork and clamp. Place in bright sunlight. After several hours, bleach the leaf with alcohol. Place in iodine solution. Observe results. Explain starch test. Repeat test with a sample of starch.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	Discuss photosynthesis and the part it plays in the maintenance of all life on the earth. Collect oxygen over water from a submerged aquatic plant in sunlight. Explain why excess oxygen is given off during this process. Place growing plant in dark box or under bell jar covered so that no light can enter. In same container place lime water to test for the presence of accumulating carbon dioxide. Explain why O is not eliminated in darkness. Why is free CO^2 present?
(2) To find out whether or not leaves carry on respiration. *An appreciation of the necessity for oxidation and consequently the importance of oxygen in the earth's atmosphere.*	Set up apparatus to prove the giving off of carbon dioxide by a plant. Arrange two bell jars of the same size on glass plates so that after placing them finally in position there can be no air access. Under one place a growing plant in its flower pot. On the glass plate place a lighted candle. Under the other jar place a flower pot of the same size containing the same amount of earth but no plant. On the glass plate place a lighted candle the same size and shape as the first one. Do **NOT** place in direct sunlight. Observe results. Discuss importance of respiration, i. e., exchange of oxygen and carbon dioxide for all living things. Experiment to prove need for oxygen. Place small growing plant in container of nitrogen. Prevent air access. Keep out of sunlight. Observe results. Compare with pupils' need for oxygen.
(3) To discover what is meant by transpiration. *A realization of the necessity for maintaining vegetation because of its value in connection with the water content of the atmosphere.*	Experiment to illustrate transpiration. Explain why leaves give off water and the effect of this on the atmosphere. Reports by pupils on tree planting and conservation in cities and country. Discuss discomfort arising from a diminished water vapor content.
. To study the INTERNAL structure of leaves. *An added understanding of the value of specialization of function.*	Examine both surfaces of several different kinds of leaves with hand lens. Note any structural peculiarities. Study leaf sections under low power. Examine charts and diagrams which illustrate microscopic structure of leaves. Explain the specialization of tissue functioning.
d. To learn that some leaves are adapted to special functions. *An appreciation of adaptation to function and an added understanding of the way in which man makes use of this adaptability.*	Examine specimens of modified leaves:—onions, cabbage, thorns, tendrils, leaves of insectivorous plants. Note the leaf like character of bracts, sepals, petals. Are stamens modified leaves? Discuss what modifications of leaves man has made of use for his own advantage.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
4. To discover how plants are essential to the life of animals and man.	Review the work of plants in connection with the oxygen, carbon dioxide, and nitrogen cycles.
a. To discuss the part played by plants in maintaining an OXYGEN balance. *An appreciation of the paramount importance of plant life in the entire life cycle on the earth.*	Emphasize the need for balanced production for plant and animal life.
b. To discuss the part played by plants in the production of FOOD substances. *A realization of the dependence of animals and man on plants for their maintenance.*	Experiment with iodine test to prove presence or absence of STARCH in as great a variety of plants as possible (not less than 10). Test various parts of same plant. Experiment with Fehling's or Benedict's test to prove the presence or absence of SUGAR in as great a variety of plants as possible (not less than 10). Test various parts of same plant. Note: There are many kinds of sugar. The tests indicated above are for grape sugar. Other sugars can be reduced so that they give the grape sugar reaction by adding a few drops of HCL before the test. Test germinating seeds for both starch and sugar. Reports by pupils on the following topics: Do all plants manufacture starch? Do all plants store starch? Why is starch stored by plants? What use is starch to the plants? In what parts of plants is starch stored? What is sugar? Is sugar stored by plants? What is the use of sugar? What is a carbohydrate? What are the general uses of carbohydrates to protoplasm? Do animals eat carbohydrates? What special plants has man cultivated for their carbohydrate content? Experiment to prove the presence or absence of **FAT** or **OIL** in as great a variety of plants as possible. Test various parts of same plant for oil. Crush the substances to be tested, place on unglazed white paper and warm gently. If oil is present a translucent grease spot will appear. Ether will dissolve oil; on evaporation the oil is left. Reports by pupils on topics similar to those suggested under starch and sugar. Experiment to prove the presence or absence of protein in as great a variety of plants as possible. Test various parts of same plant for PROTEIN. As a preliminary test, use egg albumen and test weak nitric acid and ammonium hydroxide. Discuss the presence of nitrogen in protoplasm and the importance of plants in the production of organic nitrogen compounds. Reports by pupils on topics similar to those suggested under carbohydrate and fat tests. Discuss the need for MINERAL SALTS in the growth and development of the plant. Recall the experiment which indicated this. Discuss the presence of VITAMINES. Refer to tables which indicate their presence in various foods.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
c. **To discuss the part played by plants in the development of SHELTER for animals and man.** *An understanding that human progress may be measured in terms of plant production and utilization.*	Pupils report on use of plants in the making of human shelters. Discuss the parts of plants used; the use of wood in furniture making, fencing, etc. Pupils report on the use of plants by animals in the making of shelters.
d. **To discuss the part played by plants in providing CLOTHING.**	Pupils report on use of plants in the making of clothing. Name the parts of plants that are so used and the purposes they served the plants. Discuss the relative dependence of man on animals and plants for his clothing. Experiment to distinguish the various textile fibers. Use hand lens also to distinguish differences in appearance.
e. **To discuss the part played by plants in furnishing FUEL for man.**	Pupils report on use of plants and plant products as fuel. What woods are used and why? Discuss peat and lignite. Report on formation of coal. Locate on world map the coal fields. What do they indicate in regard to the age of the earth? In regard to the climate?
f. **To discuss the part played by plants in the making of TOOLS.**	Trace the history of common implements, e. g., plow, axe, wheel, etc. Show how man's progress was dependent upon his utilization of wood. Is the need of wood for tool making increasing? Are all woods equally valuable for all tools?
g. **Classification of plants.** **In this topic there should be abundant use of illustrative material. Chief purpose of the topic is to give to the student an idea of the diversity of plant life on the earth and also the concept of developmental complexity. Chief emphasis should be placed on characteristics other than those pertaining to reproduction since this function is considered under Unit IV. To learn how generations of living things reproduce themselves.**	
h. **To discover that while all plants have the same needs, they differ structurally.** *A realization of the development of plant life from the simple one-celled water algae to the most highly specialized spermatophyte.*	Examination of plant specimens other than flowering plants, brought to the laboratory by pupils. Observation of charts, pictures, films of as many different plant phylo as is possible.
(1) **To compare an oak or chestnut with a pine or spruce.**	Field trip to observe the characteristics of the "evergreen" and deciduous trees. Laboratory study of leaves of conifers. Comparison with leaves of oaks, chestnuts, maples, etc. Observation of models, charts, and sections of stem of pine and oak.
(2) **To compare a geranium with any of the ferns.**	Field trip or reports by students of their observations in regard to ferns. Compare living fern plants with growing angiosperm. Note points of resemblance as well as differences. Laboratory exercise—comparison of sections of stem and root sections of fern with those of geraniums.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
(3) To discover what is meant by "horse tail" and "ground pine."	Examine specimens of the "scouring rush" (small species common along railways). Observe particularly the stem of the equisetum. Are leaves present? Where is most of the process of photosynthesis carried on? Examine specimens of "ground pine." Why is it so called? Notice the elongated, trailing rhizome and the simple, reduced leaves. Compare these leaves with those of the fern.
(4) To discover how the mosses resemble other plants and how they differ.	Examine pictures and specimens of true mosses. Pupils report on mosses they have collected or observed. Examine specimens of sphagnum. Where is the largest amount of chlorophyll in the leaves of the sphagnum? Why is peat moss used so extensively in green houses?
(5) To discover the characteristics of fungi.	Field trip to observe "mushrooms" and "toadstools" and "puff balls." Laboratory study of specimens or pictures of "smuts" and "rusts." Pupils report on damage to cereals by rusts and smuts. Laboratory experiment. Grow mold on bread, potatoes, cheese, etc. Examine microscopically and with low power. Laboratory experiment. Grow bacteria in hay infusion. Examine. Laboratory experiment. Examine yeast. Discuss absence of chlorophyll in fungi. What is a parasite, a saprophyte? Are all fungi harmful? What harm or damage may result from fungi? How are people trying to lessen these damages?
(6) To discover what is meant by algae.	Specimens and pictures of the four chief groups of algae. Discuss the reasons for believing them to be the lowest of living things. Compare algae and fungi with regard to chlorophyll. Field trip if possible to examine pleurococcus. Where is it found? Laboratory experiment. Scrape the leaves or stems collected from ponds. Examine for diatoms. Examine water brought in from ponds or ditches for spirogyra. Reports by pupils on "sea weeds"—"Irish moss."
i. To discover how plants are classified.	Discussion. What is classification?
(1) To consider the chief characteristics of each phylum. *An understanding of the scientific method of classification. An increased ability to observe similarities and differences in both structure and function.*	Reports by pupils on work of botanists with regard to method of classification. Study general characteristics of thallophytes, bryophytes, pteridophytes, and spermatophytes. Lantern slide illustrations of geological history of vegetation. Pupils report on stone terraces of Hot Springs, of Yellowstone; building stone used in Italy; diatomaceous earth, corallina, peat bogs, coal measures, fossil cycads, the first flowers, etc.

Unit III.

How Animals Maintain Themselves

As in Unit II, constant use should be made of fresh material. The laboratory should be supplied with aquaria well stocked with a variety of equatic forms; cages for living insects, snakes, rats, etc. The pupils should be trained in the care of the animals in the laboratory and should be encouraged to bring living material to the laboratory. Field trips, trips to zoological gardens, museums, should be frequent. As an outcome of the unit, pupils should engage actively in the conservation of wild life.

The specific objectives for this unit are:—

A. To consider the activities carried on by all animals.

1. Nutrition
2. Absorption of Digested Food
3. Circulation
4. Respiration
5. Excretion
6. Motion
7. Response to Stimulation

B. To discover the relationship of animals to other living things.

C. To consider the classification of animals.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
A. To consider the activities carried on by all animals. **1. To study Nutrition.** **a. To consider the fundamental necessity for food.** *An appreciation of the fundamental similarity of all animals.* *A realization that the fundamental need of all animals is food.*	Recall discussion of the necessity for providing plants with food. Pupils discussion of personal experience in the feeding of pet animals, stock, infants, children, themselves. Reports on observation and reading with regard to the food of wild animals. Reports on food given to animals in zoological gardens. Reports on results to animal life of famine following drought. List evidence that animals lacking food have little energy; do not build tissue; give external evidence of lack of nourishment; etc. Discuss pellagra and its social as well as individual effects.
b. To discover the kind of food made of use by various forms of animal life. *An appreciation of the variety of food made of use by animals.*	Pupil discussion of kind of food made of use by animals in the laboratory, e. g., paramecium and other protozoa, clam or mussel, cray fish, insects, earthworm, frog, fish, white rat, etc. Report by pupils on animal feeding which will lead to classification according to food habits, e. g., herbivorous, carnivorous, omnivorous, carrion feeders, etc.
c. To compare the food of plants and animals. *A realization of the dependence of living things on inorganic substances for their maintenance.*	Reports by pupils on observation of sources of food of plants and animals. Review the significance of photosynthesis. Recall the role of nitrogen in the building of protoplasm. Note the effect of nitrogenous fertilizers on the growth of seedlings or cuttings. Discuss the nitrogen cycle. Pupils report on "guano" and the phosphate beds of South Carolina. Discussion by pupils of the ultimate source of animals' food through plant food to an inorganic origin. Construct diagrams to illustrate "food cycle."

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
d. To study the uses of nutrients in the animal body. *An understanding of the need for all of the nutrients by living protoplasm.*	Review briefly the work on nutrients as found in Topic II. Are these substances present in animals as well as in plants? Test for each with animal tissue. Compare with results of similar tests with plant tissue. Are mineral salts present in animals as well as in plants? Test for mineral ash. Test for presence of water. Reports by pupils on vitamines found in animal tissue. Group discussion of influence of vitamines on growth, health, disease. Report on experimental work in connection with vitamines. List foods both plant and animal under the headings of nutrients. Discuss the uses of each to the living organism.
e. To discover that the best diet for human beings depends upon occupation, age, and physical condition of the individual and also upon climate and season. *An understanding that the relative proportions of nutrients to be used depends on different conditions.*	Group discussion and individual reports on food of grubs, caterpillars, and adult insects; food of tadpoles and adult frogs; food of kitten and puppy and adult cat and dog. Reports by pupils on foods needed by infant of 6 months; child of 6 years; of 12 years. Compare with food needed by an adult of 18 years; of 30 years; of 60 years; of 80 years. Compare the food needs of a bookkeeper with those of a truck driver or stevedore; a laundress with a seamstress or stenographer; etc. Compare the food needs of the pupils in winter and summer. Compare the food needs of a person living in southern India with those of one living in northern Scotland, etc. Discussion of general condition influencing suitable diet.
f. To learn how to plan a balanced diet. *To develop the ability to select combinations of food suited to the needs of the body.*	Each student plan a series of meals for himself which would be best under various conditions of work and season. Class discussion of these plans to ensure an understanding of the need of varying diet for varying conditions. Group projects. Plan series of meals for manual workers, sedentary workers, etc. Class discussion of these plans. Class discussion of diet for overweight, underweight, conditions of disease. Emphasize the need for a physical examination and the need for a physician's oversight of all diet in abnormal conditions.
g. To discover some common causes of indigestion. *An understanding of the real reasons for establishing good habits of eating.*	Pupil discussion of eating habits, viz:—kind of meals; regularity and irregularity of time; incomplete and complete mastication; condition of teeth; cleanliness of food, tableware and person; emotional state, worry, anger; etc.
h. To learn what is meant by substitution and adulteration of foods; to discover the reasons for these practices and the disadvantages and dangers arising from them. *A realization of the necessity for pure food and the part to be played by the citizen in making pure food possible.*	State and discuss the pure food and drug act. Discuss why pure food laws have been enacted. Define the words substitution and adulteration. What are food preservatives? Pupils report on labels of canned and bottled goods. Discuss package goods. What is cellophane? Why is it used as wrapping? Discuss the question of milk supply including in the discussion dairy inspection, pasteurization, tuberculin tested, fat content, etc. Discuss the possibilities of malnutrition arising from substitution or adulteration of food. Discuss the responsibility of the citizen in these questions.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
i. **To discuss what is meant by quack remedies and proprietary remedies.** *An appreciation of the dangers in all quack remedies and the necessity for safeguarding the public against their use.*	Pupils discuss the need for medicine; the question, "what is medicine?" Discussion of labels on patent medicines. Discussion of cure-alls. Discussion of when to consult a pharmacist and when to consult a physician. Consider again pure food and drug act.
j. **To discuss the effect of alcohol on living things.** *An understanding of the harmful effects of all narcotics both individually and socially.*	Discuss the general term "alcohol." Consider the various alcohols. Have any alcohols legitimate uses? Demonstrate the inflammability of alcohol. Demonstrate the effect of alcohol on egg albumen. Discuss the effect of alcohol on living organisms. Demonstrate the effect of alcohol on protozoa or bacteria. Discuss the experiments of dosing animals with alcohol. Discuss the effects of alcohol on the human body. Emphasize its narcotic effect.
k. **To discuss the effects of other narcotics.**	Discuss narcotics in general; their effects; "pain killers," "headache powders," etc. Emphasize the anti-social effects of narcotics (include alcohol); their connection with crime; with pauperism and general public expense.
l. **To discover the chief sources of the world supply of food for human beings.** *A realization of the interdependence of the nations of the world because of the distribution of raw foods.*	Examine and construct world maps showing the distribution of the chief articles of food. Compare with population maps. What has soil to do with population?
m. **To learn how different animals obtain their food.** *A realization of the common purpose underlying the variety of food-getting structures and habits.*	Observation of feeding habits in a variety of living forms in the laboratory, also reports on observations of students in connection with these habits in household pets, stock, wild animals seen in circuses, zoological gardens, and animal pictures seen in the movies. At least the following should be reported on: Amoeba or paramecium Hydra Cray fish, crab or lobster Oyster, clam, snail Honey bee, locust, grasshopper, potato bug, Japanese beetle, cabbage butterfly and caterpillar Earthworm Carp or other fish Frog and tadpole Milk snake or other common snake Robin, sparrow, woodpecker, eagle, duck, hen Cat, dog, wolf, seal Whale Camel Elephant Horse, cow, sheep The observations should include reports on special mouth parts if present and other structures used in the process of food getting; solitary and gregarious habits, nocturnal and diurnal preying, etc.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
n. To learn that every part of the body needs food and that therefore food must be made accessible to every part. *An appreciation that all activity must be compensated for by an intake of food.*	Discuss the general activities of all living protoplasm and the specific activities of various parts of animal body. Discussion of the fact that use results in destruction of protoplasm and the need for its remaking. Demonstrate the osmosis of soluble substances and the impossibility of osmosis in connection with insoluble substances. What foods are incapable of osmosis in the state in which they are eaten? How does a protozoa obtain its food? Why would a concentrated salt solution kill protozoa?
o. To learn why the chemical changes involved in digestion are necessary and where they occur in the human body. *An understanding of the necessity for the physical and chemical changes occurring in the digestive process.*	Pupils test wheat grains and unsweetened cracker for starch. Will starch pass through membrane wall? Chew the foods suggested. Note change in flavor. Test chewed food. Discuss the effect of ptyalin. Discuss other changes necessary for complete digestion of starch. Demonstrate action of rennin, pepsin, pancreatin, etc. Discuss general effect and specific effects of enzymes. With charts, models, etc. explain the human digestive system both structurally and functionally. List the enzymes and their sources.
p. To learn how the work of digestion is carried out by different animals. *A knowledge of specialized systems for specialized functions.*	Observe living protozoa and hydra. Supplement these observations with charts and models—showing internal structure. Observe living earthworms and insects. Supplement with dissection, charts or models to show digestive organs. Demonstration dissection to show digestive system of fish, frog, bird. Charts and diagrams to illustrate digestive organs in mammals other than man. Discuss fundamental similarity because of similarity of function growing out of universal need for food. Discuss specialization of function and increasing complexity of structure in the digestive systems of the various phylo indicated.
2. Absorption of Digested Food.	
a. To discover how and where absorption of digested food occurs. *A further realization of specialization of function accompanied by differentiation of structure.*	Recall experiments on osmosis. Review studies of root hairs. Using stained sections show villi of small intestine of a mammal. Compare villi in structure and function with root hair. Are there special organisms for absorption in protozoa? Where must absorption take place in the hydra? in the clam? the lobster, etc.?
3. Circulation.	
a. To show that the blood is brought into position to pick up the digested food. *Understanding of one of the functions of capillaries.*	Show by model, chart or drawing, arrangement of minute capillaries covering enormous areas in villi. Discuss the value of such distribution.
b. To show that the blood is largely a fluid called plasma, therefore, suited to the absorption and transportation of digested food. *Knowledge that the blood is composed of plasma, red and white blood cells or corpuscles; that the plasma consists of serum and fibrine, the latter causing clotting.*	With sterilized needle, prick finger and take drop of blood on slide. If possible, observe with microscope. If not, observe before and after drying. Discuss purpose of clotting.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
c. To show that blood contains cells carried in the plasma.	Put a drop of blood into a drop of "normal" salt solution on a slide. Examine under low power, note red corpuscles and white corpuscles—their relative number, size, and shape.
d. To explain the function of these parts of the blood. (1) Plasma-absorption and transportation of digested food to cells and of wastes from cells. (2) Red corpuscles—carrying of oxygen. (3) White corpuscles—fighting of disease by engulfing bacteria and producing antitoxins for the serum. *Knowledge of some of the functions of the blood and of the great importance of these functions.*	Compare brighter color of oxygenated blood with duller color of deoxygenated. Recall action of amoeba in feeding and compare. Report method of "making" antitoxins and vaccines at such a laboratory as that of the H. K. Mulford Company at Glenolden, Pennsylvania.
e. To learn that the blood is well distributed by the capillaries throughout the tissues, to which it can carry food and from which it can take wastes. *Understanding of another function of capillaries.*	Using the tail of a living tadpole or the web of a frog's foot, demonstrate, with the compound microscope, the distribution of the capillaries through the tissues and the nature of the capillary flow. Observe above. Discuss evidences of close distribution of fine capillaries, as seen when one pricks himself.
f. To learn that, in the human body, the heart serves as an efficient pump to send the blood over the body. *Appreciation of the normal structure and functioning of the heart.*	With model or diagram, explain the action of the heart as a pump; its structure, parts, and action. Have pupils examine chicken heart. Make a sketch of the human heart, showing position of the valves in different stages of the heart cycle. Take pulse after resting and after exercise. Compare hearts of different classes of vertebrates.
g. To study the vessels that carry the blood and their location. (1) Arteries (2) Capillaries (3) Veins *Appreciation of the fact that capillaries are where exchange of materials takes place, that arteries bring blood to them, and veins carry it from them back to the heart for pumping.*	Using chart, find principal arteries: some carrying blood from heart to lungs, others carrying it to tissues generally. Therefore, the four-chambered heart, or two-sided heart. (This anticipates a later lesson on respiration.) Describe and indicate by diagrams the location of veins for carrying blood back to heart from capillaries. Describe action of valves. Note veins on back of hand and arm; condition when pressure is exerted on back of wrist, and when these veins are massaged from fingers to wrist.
h. The Course of the Circulation. (1) To learn that the blood, leaving the "double pump," goes out on two courses, systemic and pulmonary, and that, having returned from either of these it then goes out on the other course—thus alternately reaching two sets of capillaries. (a) in tissues generally (b) in lungs *Understanding the course of the circulation, leaving question as to reason for three sets of capillaries.* (2) To learn that part of the systematic circulation is diverted to pass through the digestive tract for absorption and storage of food in the liver—the portal and lymph circulation.	By means of a chart, trace the blood from the "left" heart, through the systematic circulation, through portal, and back to heart; from "right" heart to lungs and back to "left" heart. Make simplified diagram to show the course of the circulation. By means of chart or text figure, study lacteals and other parts of lymph "circulation." Compare with general course of circulation in fish, frog, bird.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
i. To discover whether or not there is a circulation of fluids in any animals besides vertebrates. *An added knowledge of the complex way in which higher animals carry out fundamental needs.*	Observe heart of oyster or clamaortic arches of earthworm. By means of charts and diagrams discuss circulation in these animals and as many additional forms as is possible.
j. Oxidation of Foods.	
(1) To recall the lesson on use of foods, especially their use to supply energy; passage of blood into fine capillaries of lungs. *A connection between energy production and lung activity.*	Review these points.
(2) To recall experiments which showed that liberation of energy requires consumption of oxygen and production of carbon dioxide, i. e., oxidation. *Recalling of meaning of oxidation and the requirements for it.*	Review discussion.
(3) To learn what cells need energy; i. e., some need more at one time than at another: some need more than others. *Appreciation that living cells carry on oxidation.*	Discussion.
(4) To learn how oxygen can get from atmosphere to every living cell and how carbon dioxide is carried in opposite direction, recalling pulmonary and systematic circulations. *Motivation for later lessons on respiration.*	Brief questioning and discussion for motivation.
(5) To learn that air exhaled has less oxygen and more carbon dioxide than air inhaled. *Realization that body uses oxygen and produces carbon dioxide. The greater the amount of work done the greater the exchange of oxygen and carbon dioxide.*	Review discussion of experiment performed in General Science.
4. Respiration.	
a. To learn that we have organs of respiration to get air deep enough into body to bring it into contact with capillaries of pulmonary circulation, through which exchange of oxygen and carbon dioxide occur. *Understanding the reason for respiratory organs.*	Using model or chart, demonstrate respiratory system.
b. To learn the organs of respiration and their fitness for the task they must accomplish. **(1) nose** **(2) mouth** **(3) trachea** **(4) bronchi and bronchial tubes** **(5) lungs** *Appreciation of the fitness of the respiratory organs for their needs.*	Discussion and explanation of fitness.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES — CONTENT AND SUGGESTED ACTIVITIES

c. **To learn the mechanics of respiration.**

Understanding that air goes into lungs because, by muscular action, chest is enlarged changing pressure.

Use a large bottle with bottom removed and replaced by piece of sheet rubber with cord attached to center. In mouth of bottle insert cork with tube through it, a rubber balloon over end of tube inside bottle. Pull cord attached to sheet rubber and note result. Compare above apparatus to lungs in thorax and explain mechanism in body.

d. **To learn that other types of animals have the same need for respiration, but may have other methods and organs than we do.**

(1) one-celled
(2) earthworm
(3) clam
(4) insect
(5) star fish
(6) fish
(7) tadpole—frog
(8) bird
(9) dog

Appreciation of great unity of need but diversity of accomplishment in animal kingdom. Appreciation of the fact that each type of animal has apparatus satisfactory to its needs and mode of living; that our method, while not necessarily the best, is best for us.

Charts, drawings, or models may be used to show respiratory apparatus of these typical animals. The animals themselves should be used in the classroom.
Discussion of adaptation of each type to its mode of life. Discuss in what ways each method would be suitable or unsuitable for man. What special adaptations are present in camel and whale? Why?

e. **Hygiene of Respiration.**

(1) **To show that there are for us, different methods of breathing.**
(a) chest
(b) abdominal
(c) combination of above

Appreciation of the value of chest expansion and how it may be developed.

Practice the methods mentioned, noting how they are accomplished.
At home, measure chest expansion.
Discuss relative value of chest capacity and chest expansion.

(2) **To learn that, since air will come in contact with delicate tissues in the lungs, it must be first warmed, filtered and moistened.**

Appreciation of the value of nose breathing as the best method.

Discuss the best way to accomplish this.

(3) **To learn that mouth breathing is usually an indication of nasal obstruction, which should receive the attention of a physician.**

Understanding of the necessity for attention to mouth breathing.

Discuss the reasons and remedies for mouth breathing.

(4) **To learn that, since respiration means exchanging oxygen and gaseous wastes, good ventilation while indoors and plenty of exercise out-of-doors are necessary.**

Appreciation of value of fresh air and exercise.

Use experiments to discover best methods for ventilating classroom.
Study homes and report on best methods for securing ventilation there.
Note how many hours are spent in outdoor exercise each day for a week. Discuss value of strenuous exercise which promotes deep breathing, rather than "deep breathing exercises."

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

5. Excretion and Elimination.

a. To learn that, when substances are "burned" in the body to give energy, waste materials other than gases are produced which must be eliminated.

Understanding the reason for wastes.

Recall comparison of "burning" in body to that of coal or wood in furnace, in which ashes are left.

b. To learn that the blood carries certain of the wastes to organs which can excrete them.

Knowledge of methods of excretion, and necessity for regularity.

(1) kidneys
(2) skin
(3) lungs

Show model, chart, or drawings of kidneys, their location and general structure, especially the masses of fine capillaries in which are brought the wastes.

Show connecting organs, ureter, urinary bladder, and urethra. Show model, chart or drawing of skin, with especial emphasis on sweat glands.

c. To learn that the excretion of liquids on surface of body tends to regulate body temperature.

Understanding that the skin, by means of blood and sweat glands, is a regulator of temperature.

Recall experiments in General Science which show that evaporation causes cooling. Note that when we are overheated, as when exercising strenuously, we perspire most freely and are thereby cooled. Capillaries bring blood to body surface to be cooled.

d. To learn that, since wastes are excreted on the skin, they must be removed by frequent bathing.

Appreciation of the need for skin cleanliness and establishment of good habits in this matter.

Discuss the need for daily bathing of all parts of the body. Pupils check on their own habits of bathing.

e. To learn that certain parts of the food that we eat cannot be digested and must therefore be eliminated; and the best methods of securing proper elimination.

Establishment of habits which will stimulate proper elimination and appreciation of dangers of frequent use of medicines for this purpose.

Discuss the value of the following in aiding proper elimination:—

a. eating plenty of foods not too refined and condensed, but containing "roughage," as green vegetables, whole wheat bread, fruits, etc.
b. drinking plenty of water.
c. exercises involving abdominal muscles.
d. regularity of habits.

Discuss reasons why frequent use of medicines for this purpose is dangerous.

f. To discover how excretion is carried on in other animals.

Excretion is an universal result of protoplasmic activity.

By the use of charts and models show excretory organs in bird, frog, fish, earthworm. Compare with excretion in hydra, sponge, paramecium, amoeba.

g. To discover the fact that animal waste supplies plant food.

A further realization of the interdependence of plants and animals.

Note the effect of manure and cow dung on the growth of plants.
Discuss sewage disposal. Recall fertilizers as studied in Unit II.

6. Motion.

a. To learn that there is great diversity in power and methods of movement in animals.

An appreciation of the suitability of the various methods of locomotion to the life of the animal concerned.

By means of living material demonstrate the methods of movement among protozoa, viz. by pseudopodia, cilia, flagella; the motion of the tentacles in hydra and hydroid colonies; the locomotion of hydra and jelly fish; locomotion of snail; of various insects (explain muscular attachment); cray fish and crab; star fish and sea urchin; general musculature of vertebrates with illustrations of different methods of locomotion.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
b. **To study typical vertebrate joints.** *A knowledge of an articulated skeleton.*	Use joints of beef, veal, fowl, etc. Demonstrate hinge, ball and socket, and gliding joints. Show ligaments, tendons, capsule, synovial fluid, etc. Students find examples of each kind in their own bodies. Discuss articulation of skull of bird with vertebral column. Compare with mammalian articulation. Discuss perching of birds, flying of birds. Compare vertebrate joints with those of Arthropoda.
c. **To consider the general arrangement of muscles in the human body for the accomplishment of motion.** *An appreciation of the advantage of specialization of function as exhibited by the muscular system.*	Locate typical opposing muscles such as biceps and triceps; the adductors and abductors; the pronators and supinators; the extensors and flexors. Discuss muscle tone and general uses of skeletal musculature.
d. **To discover the location and use of unstriped muscle tissue in the human body.** *A realization that motion is a universal property of protoplasm, highly specialized in the muscular system of the higher animals.*	By the use of microscope slides or charts or lantern slides, demonstrate the general structural peculiarities of a skeletal muscle, heart muscle, muscles of wall of alimentary canal. Discuss the involuntary action of the muscles of the heart and the alimentary canal. Compare with similar musculature in other vertebrates.
e. **To discuss the effect of posture, occupation, and exercise on the activity of all muscular tissue.** *An understanding of the fact that the physical well-being of the body is influenced to a great extent by muscular action.*	Use charts, diagrams, pictures in the discussion on muscular activity. Call especial attention to the effects of habitual bad posture not in the musculature of the body only but in the interference with all bodily activity. Discuss the effects of over-exercise. Discuss exercise for specific defects.
7. **Response to Stimulation.**	
a. **Response to Stimuli in General.**	
(1) **To discover that irritability is a fundamental property of protoplasm.** *An appreciation of the fact that protoplasm responds to stimulation.*	Observe living protozoa. Note how they respond to contact with particles of inedible matter, to fragments of food. If possible use other stimuli, e. g. acid and alkaline solutions, heat and cold water supply diminished and increased. Note whether or not the response in each case is a purely local or general of the whole organism.
(2) **To learn that in the higher invertebrates the property of irritability is especially well developed in certain cells, organs, or groups of organs called systems.** *A knowledge of the fact that there are special structures concerned with response to stimuli. Familiarity with the terms, neurone, nerve cells, ganglion, nerve, and nervous system.*	For immediate overt response to stimulation use fresh material, e. g. hydra, snails, clams, cray fish, any of the more familiar insects. Vary the stimuli and note the kind of response, viz., local or general, withdrawal or advance, etc. Explain by diagrams and charts the simple neuro muscular cell of the hydra, the "nervous system" of the other animals observed. Motion pictures of living coral, sea anemones, star fish, squid, etc.
(3) **To learn that this process of specialization of function with regard to response to stimulation is carried to a higher degree among the vertebrates than among the invertebrates.** *A realization that advance in the development of the nervous system in the vertebrates has reached its highest point in man.*	By means of charts and diagrams show the elaboration of the nervous system through the five classes of vertebrates. Give special attention to the development of the brain as a whole and the relative proportion of the cerebrum as compared with the other parts of the brain. Show diagrams and pictures of the skulls and brain casts of prehistoric man. Compare with man of today.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
b. Response to Specific Stimuli.	
(1) Response to Touch Stimuli.	
(a) To discover whether or not all animals respond to tactile stimuli. *A realization of the universality of this "special sense."*	Observe the effect of tactile stimulation on as many different living animals as the laboratory affords. If possible have examples of protozoa and coelenterata as well as some of the higher invertebrates and vertebrates. Compare with plants.
(b) To determine whether or not there are special organs for tactile stimulation.	Discuss by means of reports supplemented by diagrams and charts the question of distribution of tactile response structures.
(c) To study the part played by response to tactile stimuli in the development of animal life. *The appreciation of the necessity for response to touch as a danger signal and therefore its importance in the struggle for existence.*	Discuss the primitive and widespread character of response to touch. Why is this advantageous?
(2) Response to Taste Stimuli.	
(a) To discover whether all animals respond to taste stimuli. *An appreciation of the widespread character of the response to taste stimuli.*	Observe response of paramecia and amoebae to particles of food and other material. Observe reaction of any of the laboratory animals to food stimulus. Reports by pupils to reaction of young of cats and dogs to taste stimuli. How has man learned to distinguish between the harmless and harmful taste stimuli?
(b) To study the human taste buds and special sense organs. *A definite knowledge of the special organs for taste in man.*	The use of charts and diagrams will be necessary for this study. Discuss how many tastes we can distinguish. Experiment to discover where special taste buds are located. Experiment to discover what is smelled and what is tasted. What does a coated tongue indicate?
(3) Response to Odor Stimuli.	
(a) To discover if animals respond to odor. *A realization of the primitive nature of a sense of smell and of its universality among animals.*	Reports on "carrion beetles"; "scenting of prey" by wild animals; fear displayed by horses at odor of fresh blood; "drag" hunt; etc.
(b) To study the human nose as a special sense organ concerned with smell. *An appreciation of the part played by the sense of smell in the struggle for existence.*	Use model or chart to illustrate structure of human nose and its nerve supply. Compare human sense of smell with that of other animals. Discuss care of nose; "colds," catarrh, mouth breathing.
(4) Response to Sound Stimuli.	
(a) To discover whether all animals respond to sound. *An appreciation of the part played by response to sound in man's development.*	Try sound stimulus on all living animals in laboratory. Distinguish carefully between air vibration as a stimulus and contact stimuli of other kinds. Reports by pupils of observed responses to sound by other animals.
(b) To study the structure of the human ear.	Use results of observation, supplemented by models, charts, and diagrams to study the parts of the human ear. Explain by means of diagrams the position of the auditory nerve and its connection with the brain. Discuss hearing and equilibrium.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
(c) To discover whether or not all animals have special organs of hearing.	Reports by pupils on observations of animals with regard to presence or absence of organs of hearing. Discuss part played by response to sound in the life of animals. Discuss lateral line in fish; experiments on pigeons with regard to equilibrium and flight.
(d) To consider the care of the ear.	Discussion of ear defects, prevention and remedy, possibility of infection through "colds," use of unclean towels, swimming pools, etc. Reports by pupils on care of the ear; cleanliness, proper method of cleaning ear drum.
(5) Response to Light Stimuli.	
(a) To discover that protoplasm responds to light. *An appreciation of the part that light plays in stimulating protoplasm to activity.*	Observe reactions of protozoa to light stimuli. Do hydra respond to light? Review effect of light on the behavior of bacteria; of green plants.
(b) To learn of some of the special structures among the invertebrates that are particularly sensitive to light. *A realization that specialization of function is accompanied by differentiation of structure.*	Observe living earth worms, cray fish, spiders, any of the insects. By means of charts and pictures, show eye spots or eyes of a number of the other invertebrates.
(c) To learn of the degree and extent of specialization of the response to light among the vertebrates.	Use charts, models, and diagrams to illustrate the structure of the vertebrate eye and its connection with the brain.
(d) To study the human eye. *A knowledge of the complexity of the human eye.*	Using model, chart, box camera, reading glass, show the principal eye structures and discuss the function of each. Discuss focus, accommodation. Experiment with varying degrees of illumination. Pupils observe effect on the eyes of each other. Pupils experiment by looking at objects at various distances. Report on any observed difference in the feeling of the eye. Discuss the part that vision has played in man's successful development.
(e) To consider the necessity for the proper care of the eye. *A knowledge of common eye defects and how they may be avoided or corrected. An understanding of how to care for the eye.*	Experiment with lenses to show what near sightedness and far sightedness are and how they may be corrected by the wearing of proper "glasses." Discuss the need for eye examination by a properly qualified physician. Discuss the correction of "crosseye," "cataract," etc. Reports by pupils on the need for clear correct vision in various occupations. Discuss the importance of correct illumination. Discuss the spreading of contagious eye diseases and how they may be avoided. Discuss the general condition of eyestrain and its effect on the health of the individual. Discuss infantile blindness and its prevention, schools for blind, etc.
(6) Involuntary Response to Stimuli.	
(a) To discover what is meant by the term "reflex act." *A realization of the primitive character of reflex action.*	Test pupillary and patella reflexes. Discuss the familiar occurrence of touching hot object and the withdrawal of the hand through no act of will. Discuss other examples of reflex action. Is reflex action common to all animals? Is reflex action advantageous?

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
(b) To learn what is meant by a "conditioned reflex."	Discuss the experiments on white rats, dogs, etc. to prove the possibility of conditioned reflex.
(7) Voluntary Response to Stimuli.	
(a) To learn what is meant by voluntary action. *An understanding of what constitutes a voluntary act as contrasted with reflex action.*	Pupil discussion of voluntary acts. Comparison with reflex acts. Discussion of part played by brain in voluntary action. Comparison of control of voluntary acts and those which are purely reflex.
(b) To study the process of habit formation. *A realization of the way in which habit formation occurs. An appreciation of individual responsibility in the formation of habits.*	Discuss the learning of walking, running, dancing, swimming, riding, flying, writing, etc., running any kind of machine. Discuss the relation of frequency of repetition on performance of any act. Discuss the acquiring of "habits" of thought and action both good and bad. Discuss individual responsibility in formation of habits. Breaking of bad habits.
B. Relationship of Animals to Other Living Things. **To discover how animals affect the life of plants and man.**	
a. To review the food cycle. *A realization of the important part that animals play in maintaining life equilibrium.*	Review the food cycle with its secondary cycles of oxygen, nitrogen, carbon dioxide and water from the point of view of the animal factor.
b. To consider how man is harmed by animal life. *An understanding of the necessity for human control of animal pests.*	Reports by pupils on property destruction by termites, rodents. Reports by pupils on crop destruction by insects. Use specific illustrations. Reports by pupils on work of moles and gophers and beavers. Study of disease carrying animals. Use specific illustrations, viz.: malaria and Anopheles; yellow fever and Stegomyia; typhoid fever and the house fly and the cockroach; possibility of spread of tuberculosis through insect agency; bubonic plague and the flea; sleeping sickness and the tsetse fly; the bed bug and louse as disease carriers; the rat as a possible spreader of disease, the ground squirrel as a host to the flea, etc. Discuss the role of bacteria and protozoa as the actual producers of disease and the part played by insects and other animals as hosts to carriers. Discuss the liver fluke; the parasitic worms of cats and dogs and their possible transfer to man, etc.
c. To consider how man is benefited by animal life. *An appreciation of the debt that man owes to animal life.*	Pupils report on animals used by man for food. Discuss the use of animals as beasts of burden. Which have been so used? Why? Discuss the uses of animal products, e. g. for shelters: for clothing in the form of textile fibers, leather, fur, feathers, buttons, etc.; for glue; for soap, jewelry, "royal purple." Discuss the uses of chalk; sponges; the development of coral islands; earthworms and soil.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
C. Classification of Animals.	a. Review briefly the fundamental needs of all animals.
1. To discover how animals maintain themselves by means of specialization. *A realization of the fundamental unity underlying specialization.*	b. By means of living material, charts, and pictures discuss phylo for carrying on the same function. (It would be well to use other illustrations than those already employed in the various topics of this unit.) c. By means of many illustrations, including lantern slides, show examples of each phylum of the animal kingdom. Illustrate chief classes under each phylum. Discuss points of similarity and differences. Make a complete classification of three or four different animals.
2. To consider the way in which scientists have classified animals. *A knowledge of the method employed by scientists in the work of classification.*	Reports by pupils on the work of the systematists. What are the advantages of scientific names?
3. To discover the orderly sequence of animal life on the earth. *An appreciation of the orderly development of life on the earth.*	By means of pictures, slides, and fossils develop the concept of a continuous succession of animal forms which have progressed in general toward greater complexity. Point out evidences of retrogression and extinction as well as those showing advance in structural design and function.

Unit IV.

How the Stream of Living Things Is Maintained

Care should be observed that living material is observed and experimented with. The topic should not be merely a succession of textbook discussions. An integral part of the work should be the observation of the development of different kinds of insects from egg stage through the adult; the development of frog eggs, tadpoles, and adult; the development of fish eggs; the breeding of white rats or guinea pigs. Emphasis should be placed on features showing facts of heredity and particular care should be employed to demonstrate the increasing care of young in the ascending scale of life.

This unit deals with:—

A. Results of Protoplasmic Activity
B. Growth of Individual.
C. Phases of Life Cycle
D. Reproduction
  1. Asexual
  2. Sexual
E. Care of Young
F. Animal Life Histories
G. Development of Fertilized Egg
H. Heredity
I. Variation
J. Selection

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
A. To discover the results of the activities of protoplasm. *A realization of the activities concerned with self preservation.*	Develop by discussion that the activities of all living things result in 1. production of energy. 2. metabolic changes. By means of observation reports the conclusion should be reached that these conditions result in the growth and maintenance of the individual.
B. To study the process of growth. *An understanding of the structural basis of growth.*	Review the general characteristics of a typical cell. Examine with high power, sections of root tip and also epithelial cells. Study in detail. With the aid of charts and diagrams explain the process of cell division. Examine mounted stained preparation of both plant and animal tissues which show cell division. Discuss the results of the process of cell division as shown in the growth of the individual as well as in the replacing of worn out parts. Does growth continue indefinitely? Compare plants and animals in regard to growth and ability to reproduce lost or injured parts.
C. To consider the phases of an individual life cycle. *An appreciation of the universality of the stages of the life cycle.*	Discuss the stages or phases of the life cycle, viz. infancy, active growing period or youth, maturity, senescence, death. Consider the fact that limitation of ability to make use of oxygen produces degeneration and death.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
D. **To discover how living things reproduce themselves.**	
1. **To learn that simple division is the most primitive method of increase.** *A realization that reproduction is a universal phase in all complete life cycles.*	Observe the simple method of reproduction developed in Pleurococcus and Gleotheca. Compare with simple fusion as it occurs in Amoeba and other Protozoa. Observe the various forms in a hay infusion from day to day. Demonstrate with microscopic preparations and charts, the method of reproduction among bacteria. Note the rapid multiplication of bacteria as shown by the growing of colonies on agar. Place some of the preparation in conditions which will promote growth; others under conditions which will hinder it. Discuss the bearing of rapid multiplication of pathogenic bacteria on disease. Discuss methods of prevention and control of bacterial growth. Pasteurization of milk, boiling of water, refrigeration of food, etc. Discuss advantage of rapid growth in the case of soil bacteria.
2. **To learn that some living things reproduce by budding.**	Observe the budding of yeast. Observe budding as it occurs in hydra. Is this method carried on by any other plants and animals?
3. **To discover that living things may reproduce by spores.**	Grow bread mold. Observe development of sporangia. Examine sporangia microscopically to observe spores. Discuss production of spores by yeast. Examine the Field Agaric or other mushrooms. If possible secure specimens which show mycelium. Observe especially gills. Examine microscopically for spores. Try to germinate spores. Does simple sporulation occur in any animals?
4. **To learn that two cells may contribute to the material from which a new cell is made.**	Observe conjugation in spirogyra. Observe similar process of zygospore formation in the union of hyphae of different strains. (These plus and minus strains may be obtained from a supply company.) Observe conjugating paramecia. Recall fission method of reproduction.
5. **To learn that some plants and animals have two methods of reproduction.**	a. Discuss, with illustrative material, reproduction among the Porifera. b. Observe and study by means of fresh material and charts the vegetative and gametic reproduction of Chlamydomonas. c. Observe specimens of hydra showing budding and ovaries and spermaries.
6. **To discover the meaning of alternation of generations.**	Study the life history of a hydroid. Use fresh or preserved material as well as charts. Study from fresh material the life history of a fern. Compare the sporangia of the cinnamon fern and Bracken. Observe fern prothallia (gametophyte generation). Observe antheridia and archegonia. By means of microscopic slides and charts explain in general fertilization. Explain without detail the development of the sporophyte from the union of the sperm and egg nuclei. Compare life history of fern with that of moss. In each, which is the conspicuous generation?

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	Is there an alternation of generations in any of the animal phylo in addition to the example of Coelenterata studied? Is there an alternation of generations in any of the spermatophytes? If there is, which is the conspicuous generation? Are there advantages or disadvantages in alternation of generations?
7. To study reproduction as it has developed in angiosperms. **(a) To discover the function of the flower.**	Review very briefly the parts of a flowering plant which are concerned with its own maintenance. Study, using fresh material, as great a variety of different kinds of flowers as is possible. Begin with a relatively large simple flower for first study. Supplement the fresh material with pictures and slides of other flowers. The material should include examples of solitary flowers and various kinds of inflorescence; complete flowers of several types; incomplete, staminate, pistillate, monoecious, dioecious flowers. What are perfect flowers; what are the essential organs of a flower?
(b) To study pollination.	Study pollination. If possible field trips should be taken on which the agency of insects in pollination could be observed. Discuss the functions of color, odor, honey, nectar, shape of corolla, position of stamens and pistil, etc.
(c) To discover how cross pollination is secured.	Use fresh material, charts and diagrams to illustrate cross pollination. These illustrations should include examples of wind pollination as well as insect pollination; and examples showing the maturing of stamen and pistil of the same flower at different times. Discuss wind and insect pollination from the standpoint of efficiency in securing pollination. Do any animals other than insects act as pollen carriers?
(d) To learn how seed is formed from the union of two cells.	Recall briefly the gametic reproduction of Chlamydomonas as well as the union of sperm and egg in the fern. Germinate pollen grains in sugar solution and examine with microscope. Examine ovules—notice attachment. By means of charts show the union of egg and sperm nucleus. What is a seed? Why is fertilization usually followed by the withering and falling of petals and sepals? Watch growing ovaries of bean, pea, Evening Primrose, or other common plant.
8. To study reproduction as it has developed among animals.	Recall methods of reproduction already studied among Protozoa, Porifera, and Coelenterata. By means of specimens, charts, and models study the reproductive organs of an oyster or clam, an earthworm, a grasshopper or other insect, a cray fish or lobster, a starfish, a trout or other fish, a frog, a snake, a sparrow or other bird, a mouse or other mammal. Emphasize in the discussion the development of reproductive systems which will ensure fertilization and the consequent production of offspring.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
E. To learn how the young of plants and animals are cared for.	
1. To study seed dispersal. *An appreciation of the numerous provisions to ensure the continuance of the species.*	Estimate the number of seeds produced by a single plant. What would happen if all the seeds fell within a small space? Compare with competition in economic world; with the results on human beings of crowded housing. With the aid of fresh material examine a variety of fruits with their seeds. Discuss the production of fruit as the outcome of the stimulus of fertilization. How do fruits aid in seed dispersal? List adaptations for wind dispersal; water dispersal and dispersal by animals both externally and internally and seed dispersal by the plant itself.
2. To study the dependence of embryonic development on food supplied by parent organism.	Study seeds to determine whether or not they contain a food supply. What is necessary for seeds to germinate? Compare seeds before and after germination in regard to stored food. Prove that the stored food must be made soluble by enzymes. (Recall work on nutrition.) Prove that the embryo lives on this food. Prove that after this reserve food is exhausted it has developed so that it can make its own food supply. Study the feeding of the honey bee larvae. Is it for the same purpose as the deposition of food in the seed? Examine the eggs of a fish, frog, bird for study of food supply. What is the provision for the feeding of the embryonic mammal?
3. To discover whether or not some form of shelter or protection is provided for young.	Discuss the part played by both dry and fleshy fruits as seed protectors. Discuss the egg laying habits of insects, the egg case of the spiders; the gelatinous masses of frog eggs; the nest of the stickleback; the various nests and other shelters of birds and mammals. Discuss the migration habits of such insects as the monarch butterfly; such fish as salmon, shad and eels; such birds as the warblers and the golden plover; such mammals as the fur seal. These journeys are apparently for the purpose of securing an appropriate environment for the young.
F. To study the changes that take place in animals as they develop from egg to adult. *A realization of the importance of provisions for the young in the struggle for existence.*	Observe the changes through which a butterfly or moth passes from egg to adult. Compare with the life history of other insects. A sufficient number of studies should be made to demonstrate clearly both complete and incomplete metamorphosis. Compare with the life history of the oyster, the sea-urchin, the frog, the fish. Discuss the difference between the baby chick and the young robin. Why is more care needed for the young mammal and for a longer time than for the young of other animals? Is this an advantage or a disadvantage? Are all mammals alike in this respect? Is there any advantage in the long period of human infancy?

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
G. To study the development of the fertilized egg. *A comprehension of the unbroken continuity of the stream of living things in the world.*	Review briefly the structure of a typical cell and the process of cell division. By means of charts, diagrams, and microscopic preparations study in detail the maturation of the egg and sperm cell. Compare the behavior of chromosomes in division of body cells with the same phenomenon in the division of sperm and egg cells. Note the constancy of the number of chromosomes in any given form. Trace the development of the embryo from the time of fertilization until its growth is completed. Use charts or other illustrations which show the similarity of the changes in a great number of different forms. Discuss the growing elaboration of structure in the higher animals. Discuss the unbroken continuity of germ cells as compared with the somatic cells. Are there parents and offspring in the case of Protozoa and Bacteria? Has there ever been a break in the line of the ancestry of any one celled form since its first appearance on the earth? Pupils discuss whether or not there could be gaps in their own ancestry.
H. To study the problem of heredity.	
1. To prove that "like produces like." *An appreciation of the fact that every organism in its characteristics is the result of the combined action of heredity and environment.*	Observations reported by students which illustrate the saying "blood will tell" and the general statement that offspring resemble parents. Illustrations should be drawn from the pupils own first hand knowledge in regard to plants and animals as well as human beings. Distinguish between physical similarities and resemblances due to influence of surroundings. Are there any evidences that offspring do not resemble parents?
2. To discover the probable physical basis of inherited factors.	Study the probable connection between heredity and the chromosome. Pupils report on the work of Jennings and other biologists in regard to the physical bases of heredity.
3. To discover that dissimilar parents may produce offspring with characteristics of either or both parents.	Pupils experiment in the laboratory or in their own gardens on cross breeding different varieties of corn or peas. Discuss with illustrations the work of Mendel. Pupils report on cross breeding of other plants and of animals for experimental proof of inheritance of physical factors. Reports on successful cross breeding that have results in forms of economic importance. Reports on inheritance of physical defects among human beings, e. g. feeble-mindedness. Are diseases inherited? Can physical defects be bred out?
4. To learn how man is able artificially to "reproduce" some plants by cutting, grafting, budding.	Experiment with cutting using Begonia and Bryophyllum leaves. Describe the process of budding and its results. Pupils report on the use of this method in the propagation of the citrus fruits. Is the succeeding generation affected? Plant twigs of willow, poplar, geranium or coleus in pots. Do these take roots? Will they resemble parent stock?

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	"Graft" a twig on to a stock. Cover the wound quickly with wax. Does the grafted twig or scion grow to the stock? Does it alter the offspring of the stock? Are its seeds or fruits altered? Discuss skin grafting, transplanting of animal organs. Do they alter the animal so that it resembles the one from which the skin or organ was removed?
5. To discover whether or not all characteristics are transmissible.	Reports by pupils on the results of the following: a. Foot-binding as formerly practiced in China; the piercing of the ears, nose, lip as it is carried out in some African tribes. Is there any evidence that the result is transmitted? b. Docking of tails of horses; the cutting of the ears of some terriers. Are these results inherited? c. Dwarf trees (plum, orange, pine) of Japan. Do the seeds produced give rise to dwarf descendants? (1) Will acquired traits be inherited? (2) Is training or education shown in succeeding generations? (3) Can man control or influence human inheritance? d. Name the factors which are potent in the natural selection of survival types. e. Selection in plants and animals. (1) Compare different breeds of modern hens in regard to egg laying. (2) Compare different breeds of cattle in regard to milk production; different breeds of sheep for differences in wool. (3) Compare the different varieties of cabbage (cultivated cabbage, cauliflower, Kohlrabi, Brussels Sprouts) with the wild cabbage of Europe. (4) Compare wild strawberries, raspberries, etc. with the cultivated fruit. (5) Compare bearded and beardless wheat. f. Discussion of the following topics: (1) How do variations occur? (2) Selection is continuously at work. What evidence is there of the truth of the statement? (3) Selection is taking place in wild life. Cite proof. (4) Selection is being used by man in the production of both plants and animals.
I. To understand what is meant by the term variation. *The realization of the inherent variability of protoplasm.*	Observe the following: 1. a. Ear of corn. Are the kernels exactly alike? What are the differences? b. Flowering plant bearing several blooms. How do the flowers differ? c. Sassafras leaves from same plant. How do they differ? d. Litter of puppies. How do they differ? e. Hands, ears, feet, eyes of each student. How do they differ? 2. a. Ears of corn, heads of wheat, apples, plums, etc. from different plants. How do they differ? b. Shells of snails, oysters, clams, etc. How do they differ? c. Cattle, horses, sheep, pigs, dogs, cats. Comparison of different breeds.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

d. Members of class compared for stature, weight, eye color, finger length, hand clasp, etc.

e. Comparison of physical characteristics of human twins.

3. a. Comparison of different fields of same kind of corn, wheat, etc.

b. Comparison of herds of cattle or droves of sheep of same kind but in different pastures.

c. Comparison of flocks of chickens of the same kind but fed on different foods.

4. Discussion of the results of these observations to decide whether variations are due to:

a. External or environmental factors such as heat, light, food, etc. or

b. Internal or inherent factors.

5. Discussion of the possibility and desirability of producing variations.

J. To discover the meaning of selection.

An appreciation of the continuous process occurring in nature which brings about the survival of the forms best fitted to their environment and a realization that it lies within man's power to alter some plants and animals so that they are of greater use to him.

1. Discussion—

a. Are the plants and animals of today exactly like the living organisms of past geologic ages? Recall study of classification of plants and animals.

(1) Compare the horse of today with the horse of preceding ages.

(2) Compare plants found in coal measures with tropical plants of today.

b. Why are plants and animals of today exactly like those of the past?

c. Define selection, natural selection, artificial selection.

2. Report the work of:

a. De Vries (Evening Primrose)
b. Blakelee (Jimson weed)
c. Sanders (Navel orange)
d. Burbank (Spineless cactus, etc.)
e. Morgan (Fruit fly)
f. Animal breeders

What are mutations? How do they arise?
What is the physical basis for selection?

Unit V.

Plant and Animal Forms in Relation to Environment

A maximum use of field trips should be made throughout the topics included in these units. Pupils should be encouraged to observe mutual relationships at all times.

If Units II and III have been studied in detail, topic A of this unit may be shortened by the omission of experiments previously performed and the results recalled by means of reports.

This unit considers:—

A. Factors of Environment
B. Ecological Units
C. Contacts Among Organisms
D. Adaptation
E. Man's Response to His Physical Environment
F. Races of Men

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
A. Factors of Environment	
1. To discover the wide distribution of living things. (General, not specific grouping.) *A realization of:* *a. The great variety of plants and animals in the world.* *b. The fact that living organisms are to be found practically everywhere in the world.*	Observation and examination of specimens, pictures, lantern slides, moving pictures which show plants and animals from all parts of the world. This illustrative material should be sufficiently extensive to give an adequate idea of the great extent and variety of living things. These illustrations should be supplemented by additional material gathered by the pupils. Trips to museums, zoological gardens, forest preserves, etc. Field trips to conveniently located places, e. g. streams, woods, fields, caves, hillsides, etc., which may furnish additional information in regard to the distribution of living things. Reports by students of their own observations in their longer trips in summer vacations, etc.
2. To discover where plants and animals are distributed in the world. (Grouping — introduction of idea of limitation.) *A realization that although living organisms are to be found nearly universally in the world, that there is a characteristic flora and fauna of geographical regions. An understanding that life regions are not dependent upon nor coincident with the artificial political geography divisions.*	a. Analysis of material used in "1" to determine geographic distribution of plants and animals. b. Maps should be constructed showing the chief animal and plant forms of the following regions: (1) North American region (2) South American region (3) Eurasian region (4) African (southern) region (5) Oriental (6) Australian (7) Arctic (8) Antarctic c. A consideration of these regions to determine, if possible, what the limiting physical factors may be.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

3. To discover what is meant by habitat, range, life zone.

A conception of how the universal spread of plant and animal forms is limited by
a. Natural barriers
b. Man's intervention

Analysis of material in "1" to determine the life forms occurring in

a. Different kinds of habitats. In this study should be included:

(1) Fresh water lakes, streams
(2) Swamp or bog
(3) Open meadow land
(4) Forest land
(5) Dry plain
(6) Desert
(7) Hills and valleys
(8) Mountains
(9) Sea coast
(10) Open sea

Local field trips will add to the pupil's knowledge of distributional biology.

b. Range distribution.

Reports on the distribution of some of the familiar wild plant and animal species should be made by the pupils: —gypsy moth, house fly, Mediterranean fruit fly, bison, wheat rust, violet, golden rod, etc. Also additional reports on the range distribution of plants and animals as it has been affected by man.

c. Life zones with special reference to U. S.
Maps should be constructed showing the distribution of plants and animals in the American life zones.

d. An analysis of the general life regions as determined by the preceding study to determine whether or not these more restricted subdivisions of distribution are true of all the larger areas.

4. To determine the environmental factors which influence the distribution of living things.

A realization that the environment supplies the fundamental needs of all living things.

A review (brief) of the needs of all living organisms (see preceding general topics), i. e., water, heat, light, air, food.

A discussion of these factors to develop the generalization that they may be grouped as follows:

a. Climatic factors:

(1) water
heat
light
air (wind)

(2) Review climatic zones with reference to the variations in the factors mentioned. Maps should be constructed to demonstrate rain-fall, direction of winds, temperature, etc.

b. Chemical factors.
food—character of soil
water—as food
air—chemical composition

c. Geographic factors
These include

(1) the distribution of land and water masses according to zonal location and therefore these general geographic factors depend upon climatic factors

(2) chief topographic characteristics. These also result in climatic differences.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

5. To discover how plants and animals react to these factors.

A study of the reaction of plants and animals in response to their needs as supplied by the environment.

A realization of the need for water and the consequent limitation of life to those parts of the world in which there is a water supply.

a. Water
- (1) Universal need
- (2) What evidence that it is needed by all living things?
  Composition of protoplasm
  Composition of sap
  Composition of coelomic fluid
  Composition of blood
- (3) Demonstration experiment:
  The chemical changes that distinguish living protoplasm can take place only in the presence of water.
- (4) Recall from student's own experience the phenomena of thirst.
- (5) Distribution of water in the world:
  - (a) Atmosphere
  - (b) Surface water:
    oceans
    bodies of fresh water
  - (c) Ground water
  - (d) Soil water
- (6) Compare abundance of life in Amazon valley with life on the Sahara. Account for vegetation in oases.
- (7) Does the presence of water indicate a reason for this wide distribution of living things?
- (8) Review part played by water in the life of the plant.
  Experiment (if these have not been included in previous general topics) to illustrate:
  Hydrotropism (roots)
  Absorption (root hairs)
  Transpiration (leaves)
  Growth of seedlings with and without water
- (9) Review part played by water in the life of the animal.
  - (a) Experiment to illustrate effect of drought on protozoa and other lower forms.
  - (b) Pictures to illustrate the use made by wild animals of water holes.
  - (c) Pictures to illustrate changes in animal life in a given region (notably Africa) on the disappearance of water holes through the agency of long droughts or the agency of man.

The significance of an optimum temperature for protoplasmic activity. An understanding that the limits of comfortable living are bounded by a comparatively few degrees of temperature.

b. Heat
- (1) A study of the effects of changes of temperature on living organisms.
- (2) Experiments to illustrate the effects of changes in temperature on protoplasmic activity.
  - (a) Slides of Elodea, etc. Pupils note streaming of protoplasm. Increase and decrease temperature of slide. Pupils note effect on movement of protoplasm.
  - (b) Slides of living Amoeba, Paramecium, etc. Repeat as above.
  - (c) Effect of temperature changes upon the growth of seedlings.
- (3) Reports by pupils of the results of their own observations on the effects on house plants of varying conditions of temperature.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES | CONTENT AND SUGGESTED ACTIVITIES

(4) Reports by pupils of the effects of temperature changes on vegetation in general, e. g., garden plants, field crops, forests.

(5) Report by pupils of the effects of temperature changes on animal life in general, e. g., fish, frogs, snakes, birds, bears, prairie dogs, squirrels, etc.

(6) Report by pupils of their own reaction to temperature changes.

Do the differences in temperature to be found in the different parts of the world help to determine the distribution of plant and animal life?

A comprehension of the important role of sunlight in the life of all organisms.

c. Light.

(1) A study of the effect of light on living organisms.

(2) Experiments to illustrate the effect of light on plants. (If this has been covered in preceding work the experiments may be omitted.)

- (a) Experiment to illustrate heliotropism
- (b) Experiment to illustrate photosynthesis
- (c) Experiment to illustrate growth of seedlings in presence and absence of light.

(3) Pupils report on the effect of presence and absence of sunlight on greenhouse plants.

(4) Pupils report on the effect on plants grown in the absence of light. (Mushroom cultivation.)

(5) Pupils report on effect of sunlight on bacteria.

(6) Experiments showing the reactions to light of earthworm and cray fish.

(7) Pupils report on

- (a) Nocturnal habits of moths, owls, porcupines, lions, etc.
- (b) Diurnal habits of sheep, cattle, etc.

(8) Pupils report on effect of "sunlight lamp" in greenhouses and on poultry farms.

(9) Pupils report on prevalence of rickets in cities in which there is much smoke and fog.

(10) Does the rotation of the earth and the inclination of its axis influence the amount of sunlight of different regions?

(11) Does this influence the distribution of living organisms?

d. Air

(1) Is air essential to living things?

(2) Reaction of plant life to air

- (a) Experiment to show that green plants breathe. (Exchange of O and CO_2.)
- (b) Experiment to show the effect of air deprivation in green plants. (Coat the upper and lower surfaces with wax of all the leaves of any small green plant.)
- (c) Experiment to show the effect of the presence and absence of air in the growth of seedlings.
- (d) Experiment in home gardens to show the effect of overcrowding. (Special attention to lack of respiration.)
- (e) Pupils report on reasons for the thinning out of seedlings.
- (f) Report on aerobic and anaerobic bacteria in relation to their reaction to oxygen.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES | CONTENT AND SUGGESTED ACTIVITIES

(3) Reactions of animal life to air.
  (a) Experiment to show reaction of Protozoa when introduced into water which has been thoroughly boiled and to which there is no subsequent air access.
  (b) Teacher report on the effect of the deprivation of oxygen on living animals.
  (c) Pupils report own reactions to differences in air content and air pressure.
  (d) Report on the story of the "Black Hole of Calcutta" and Libbey Prison.
  (e) Artificial respiration.
    Demonstration of Shaefer Method of Resuscitation
    Use of pulmotor explained
(4) Is the physical mixture of gases which makes up the atmosphere the same everywhere in the world?
  (a) Has altitude any effect on the atmosphere?
  (b) Does atmosphere play any part in life distribution?
(5) Discussion of the part played by wind in the distribution of moisture and consequent effect on life.
(6) Discussion of the effect of wind on sea-coast vegetation.

(1) *The absolute dependence of living things on food supply.*

(2) *The limitations imposed on food supply by nature.*

e. Food
To show that all living organisms depend upon food for the continuance of their existence.
(1) Reactions of plant organisms to food.
  (a) Experiment:
    Growing bacteria in culture medium
    Effect on bacteria of sterile medium
  (b) Experiment:
    Growing seedlings in solution of various mineral salts.
  (c) Report of pupils on feeding of house plants.
  (d) Report of pupils on rotation of crops and the use of fertilizers.

Solutions used:

1. *Distilled water*
2. *Calcium sulphate*
3. *Calcium phosphate*
4. *Magnesium sulphate*
5. *Sodium chloride*
6. *Iron chloride*
7. *Potassium nitrate*

(2) Reaction of animal organisms to food.
  (a) Experiment: Effect on Protozoa and other lower forms when fed with distilled water.
  (b) Report by pupils on feeding of domestic animals.
  (c) Report by pupils of effect of starvation on:
    animals
    human beings
  (d) What conditions produce famine?
  (e) Report on "hunger strikes"
  (f) Discussion of the effect of the distribution of food on the distribution of life

Summary of the relationship between the distribution of living organisms and the climatic and chemical factors of their environment.
(1) Compare the native plant and animal life of the following regions:
  (a) Alaska and Florida
  (b) Arizona and Louisiana
(2) Pupils report on the distribution of life forms in Pennsylvania.
(3) Construction of world maps showing significant differences in climatic and topographic factors with corresponding differences in the distribution of living organisms.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
B. Ecological Units **1. To determine what factors are dominant in the production of plant and animal associations.** **2. To gain a knowledge of the principal ecological units which maintain a balance in nature.** *A realization of how climatic geographical and chemical factors create plant and animal associations which survive in the struggle for existence.*	1. Field trip to fresh water pond to observe kinds of living organisms. a. (1) Algae (2) cat-tails (3) arrowheads (4) protozoans (5) small crustaceans (6) insect larvae (7) fish b. What is the dominant environmental factor to which these diverse organisms are adapted? 2. Similar studies from direct observations or the examination of illustrative material should be worked out for at least one association of each principal type. a. (1) fresh water associations, (2) salt water associations, (3) swamps-salt and fresh — Hydrophytes b. (4) sand societies, (5) health societies, (6) cactus deserts, (7) tropical deserts — Xerophytes c. (8) meadows-prairies-pasture, (9) thickets, (10) deciduous forests — Mesophytes From these studies the dominant part played by water, heat, light, wind and soil should be recognized in the formation of the various societies. Attention should be directed to principal adaptations of chief forms in each society. Why are the native plant associations of Indiana similar to those of Ohio; of Kansas similar to those of Nebraska? What ecological units are to be found in your neighborhood? Has man destroyed or created any ecological units? Discuss the succession of plants in a given locality. Compare the present forest growth in Northern Wisconsin with the forests of the same region before lumbering occurred. Do the same kind of trees grow in any region following a forest fire? Is there any succession of plants other than those of forest trees which occurs in nature? Would a list of plants growing in a meadow, field, etc. be the same year after year? What conditions would account for differences? Has man made any use of such successions? Has he supplemented or modified them?
C. Contacts Among Organisms **1. Symbiosis (Living Together)** **a. To learn stages of interdependence of living things.** *An appreciation of the gradual modifications of organisms (in both structure and habits) that live together resulting in mutual or one-sided advantage.*	Consider: Organisms which are competitors with little or no division of labor among them. (The usual condition.) Associations of living things that do not involve structural modification (crab and sea anemone). Associations that are more intimate and involve structural modifications (alga and fungus in a lichen). Associations that are still more intimate and involve the loss of power for independent existence (slave ants).

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

2. Parasitism

a. **To learn that some plants and animals become partly or wholly dependent upon others whom they do not help in turn.**

D. Adaptations

1. **To determine what is meant by the term adaptation.**
2. **To discover whether or not there is a relationship between adaptation and environment.**

A realization that plants and animals must be fitted to the conditions under which they live.

CONTENT AND SUGGESTED ACTIVITIES

Study the mistletoe; the dodder.
Study the bot fly; the liver fluke.

1. a. Observe living frog or fish; birds and insects both land and water forms, in the laboratory.
The pupils should discover from these observations the adaptations in regard to the following:
(1) surrounding medium
(a) shape
(b) external covering
(c) color
(d) locomotion
(e) respiration
(2) food and food getting
(3) temperature

b. Observe in the laboratory adaptations in the plants as follows:
(1) water plants—plants used in aquarium. Observe roots-stems-leaves-internal spongy structure. If possible note stomata on upper surface of leaf in pond lily or other water plant with floating leaves.
(2) Cactus—observe for reduced leaf surface—spines—thickened stem, etc.
(3) Grasses—observe arrangement and shape of leaves. Observe with reference to possible reaction to wind.
(4) Observe arrangement of leaves on various plants with special reference to their adaptation to secure light for all of the leaves.

c. Additional illustrations of adaptations should be secured in the form of specimens' pictures, etc. These should be grouped finally under these headings:
(1) Adaptations for food getting
(a) beaks and feet of birds
(b) teeth of mammals
(c) mouth parts of insects
(d) root hairs
(e) leaves—pitcher plant
(2) Adaptations for locomotion
(a) wings—bats, birds, and insects
(b) fins—fish
(c) appendages of—bull frog toad, tree toad, flying frog
(d) legs and feet—cat, dog, horse, and camel
(e) flippers—seal and whale
(3) Adaptations for protection
(a) exoskeleton of cray fish and insect
(b) fur, feathers, scales of vertebrates
(c) bark and thorns of plants
(d) subcutaneous fat of whales
(e) shedding of leaves of deciduous trees
(f) nemotocysts of hydra
(g) color of many moths
(h) sting of a bee
(4) Adaptations for securing the production and care of young
(a) color of flowers—day blooming
(b) color of flowers—night blooming

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

(c) odor of flowers
(d) seed and fruit dispersal
(e) special devices for cross-pollination
(f) oviposition of locust
(g) swimmerets of female crayfish
(h) clitellum of earthworm
(i) use of tail by female opossum for support of young

2. Reports of student observations in regard to relationship between environment and adaptations.

These reports may be the result of observation of living specimens in their natural environment or the result of trips to zoological gardens, museums, or present specimens in schools, or material drawn from pictures.

Some suggestions of animals which show adaptations to environment.

a. Walking stick—structure and color
b. Preying mantis—color chiefly
c. Katydid—color and shape
d. Crayfish—color
e. Trout or—color of ventral surface
Shad—color of dorsal surface
f. Flounder—color and shape
g. Tiger—stripes—light and shadow
h. Weasel—winter and summer coats
i. Sage-brush—loose and shallow root system
j. Cactus—fleshy stem—no true leaves
k. Mesquite—water stored in roots

What structural adaptation in the human hand has aided in man's control of his environment?

E. Man's Response to His Physical Environment

1. To understand that man is dependent upon and influenced by the factors of his physical environment.

A realization that while man is dependent upon his physical environment for his continued existence that he may shape his environment to a greater degree than any other organism.

a. Review the chief physical factors of the environment. (Water, heat, light, air, and food.)

b. The dependence of man upon water for:
(1) metabolic activities
(2) moisture necessary for work of mucous membranes. (Effect of dry air on eyes, nose, throat, lungs.)
(3) cultivation of crops, therefore, depends upon water for food supply.
(4) necessity of water for domesticated animals, therefore, man depends upon water for animal food supply; for clothing (silk, wool).

c. The dependence of man upon heat for:
(1) metabolis activities
(2) food supply

d. The dependence of man upon light
(1) necessity of light for food supply
(2) relation between sunlight and diseases

e. The dependence of man upon air
(1) necessity for exchange of oxygen and carbon dioxide
(2) necessity for oxygen in the production of energy
(3) necessity for oxygen in the growth and development of plants and animals used as food
(4) effect of alterations of air pressure

f. The dependence of man upon food
(1) necessity for growth, repair, production of energy
(2) effect of famine
(3) effect of inadequate diets

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
2. **To consider the degree to which man can alter the physical factors of his environment.**	Reports on: a. Control of water factor (1) drainage (2) irrigation b. Control of heat factor (1) heating of orange groves on reports of lowered temperature, to prevent heat radiation (2) artificial heating of greenhouses, buildings in which animals are housed, man's own dwellings (3) refrigeration as a preservative, etc. c. Control of light factor (1) artificial lighting of dwellings, etc. (2) artificial sunlight used for medicinal purposes and to stimulate growth and other activities in plants and animals d. Control of air factor (1) shelter from severe winds (2) filter dust from air in some buildings (3) ventilating systems e. Control of food factor (1) increased production (a) quantity (b) quality (2) selective breeding (a) new foods (3) preservation of foods f. Control of plant and animal pests (1) study bulletins of Bureau of Agriculture g. Control of disease producing organisms (1) diseases prevalent in different districts, e. g., hook worm in the southern United States; malaria in Italy and southern United States; tropical diseases; communicable diseases in general; medical inspection and examination; quarantine; health laws; Boards of Health. (2) clearing of Cuba of yellow fever; sanitation of Canal Zone, etc. h. Control of natural resources (1) forestation (2) schools of agriculture, horticulture, etc. (3) schools for study of animal care and breeding (4) mineral resources and their conservation and development
3. **To consider the part played by physical factors of environment in the distribution of mankind.**	Construct maps showing general distribution of population of the world. a. Note the general agreement between density of population and the functioning of the most favorable physical factors.
F. Races of Men 1. **To consider the resemblances among all human beings.** *Appreciation of essential unity of human race.*	A study of resemblances. a. Physical characteristics of all living organisms b. Physical characteristics of all vertebrates c. Physical characteristics of all mammalia d. Physical characteristics of all human beings (1) How do human beings resemble one another? (2) Have human beings always had the structural peculiarities of modern man?

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
2. To consider variations among men. *Survival value under primitive conditions of special physical character.*	A study of differences. 1. Analysis of differences and a general classification of differences (a) skin pigmentation (b) structure and texture of hair (c) facial angle (d) shape of skull
3. To determine whether or not there are constant variables.	a. Are these differences constant enough to constitute separate races? b. Are the differences or resemblances more numerous, more fundamental? c. Names of recognized races (1) Are all of the people of the world grouped under these races? (2) Is there any question in regard to any people so far as race is concerned?
4. To consider the distribution of races.	Maps showing general racial distribution. a. Compare these maps with ones which might represent racial distribution in past ages. b. Was man always in the world? c. Where have remains of primitive man been found? d. How may races have originated? (1) migration (2) variation (3) natural selection (4) transmission of characters

SAMPLE LESSON IN UNIT IV

How the Stream of Living Things is Maintained

Problem

To learn some asexual methods of reproduction.

Materials

Hay infusion, compound microscope, bread, seeds, potato, dishes.

Procedure

(a) If possible, examine under a compound microscope a drop of water from a hay infusion which has been standing a few weeks. Note the varied flora and fauna. Where have these forms come from?
(b) Place a piece of bread in a warm, damp place for several days. What organisms appear?
(c) Show a potato sprouting in sand or sawdust, also germinating seeds. (These should be started several days ahead. In fact, it is helpful to keep a constant supply of growing seedlings on hand for use.)

Introduce terms fission, vegetative reproduction, spores, seeds.

Conclusion

Since all plants and animals die sooner or later, new individuals must be forthcoming if the race is not to die out. Plants and animals have found various means of accomplishing this renewal of the race, such as, (a) simple self-division or fission; (b) special cells set apart (spores); (c) a complicated process (seeds).

Development

What happens when reproduction fails? Consider such cases as (a) the heathen; (b) certain cultivated plants; (c) childless families.

SAMPLE LESSON IN UNIT V

Plants and Animal Forms in Relation to Environment. C—Adaptations

Problem

To show how plants adjust themselves to meet the varying amounts of water in their environment.

Materials

Cacti, sedum or live-forever, house-leek, tradescantia growing in water, aquarium plants, potato, cork.

Procedure

Compare these plants as to their adaptations to water adsorption, water conservation, extent and nature of root system.

Observations

(a) Reduced stems of desert plants, lack of leaves, cuticle.
(b) Delicate texture of aquatic plants for which the supply of water is no problem.
(c) Cork covers exposed stems where water conservation is necessary.
(d) Certain plants must dig deep for water, hence tap roots. They can resist drought—dandelion.
(e) Some obtain their water near the surface from fairly constant supply—fibrous; grasses (sod).

Conclusion

In both plants and animals an ample supply of water is a constant necessity.

Three adaptations of plants to obtain water are:
1.
2.
3.

Three adaptations of plants to conserve moisture are:
1.
2.
3.

Suppose all plants had the same arrangements, which would suffer in the desert? In a swamp?

Development

Name ten (10) plants in the home and find out under what conditions they are healthiest.

Name ten (10) garden plants. Under what conditions do they reach their best or maximum development?

SAMPLE LESSON IN UNIT V

Plants and Animal Forms in Relation to Environment. C—Adaptations

Problem

What is meant by the term "adaptation"?

Material

Living specimens of fish, frog, bird, and preserved specimens or pictures of these animals.

Procedure and Observations

Note by sketches or otherwise, concerning each form—

1. General shape
2. External covering
   a. general character
   b. outgrowths
   c. color
      distribution of color
3. Locomotion
   a. general method
   b. organs used
   c. comparison of fin, foot, and wing
4. Respiration

Conclusion

1. A fish is fitted for or adapted to the medium in which it lives by
2. A frog is fitted for or adapted to the medium in which it lives by
3. A bird is fitted for or adapted to the medium or media in which it lives by

This adjustment to the environment is called adaptation.

Development

Are these observations true also in regard to the other animals shown in pictures or as preserved specimens?

What is the effect of removing fish from its usual surrounding mediums? Why?

What would be the effect of complete and long continued submersions in water of any bird? Why?

What advantage to the animals studied is to be found in their general shape?

What advantage to the animals studied is to be found in their external covering?

How are the scales of a fish arranged? The feathers of a bird?

Is there any relation between the color of the animals studied and their surrounding medium?

Course of Study in Physics

Introduction

The importance of effective and pedagogically sound instruction in physics in secondary schools is immediately apparent when one considers the contributions of physical science to human welfare. The enjoyment, health and continued progress of mankind depend increasingly upon a proper understanding and use of physical facts and laws.

Adequate provision for public education can not be made by offering instruction in physics to the favored few who are preparing to enter college or by deferring it until college is reached. The great majority of our pupils will continue to end their educational careers in the high school. These pupils need to be oriented in the scientific age in which they must live. Any secondary school curriculum, therefore, which neglects to provide an opportunity for each pupil to study the physical sciences, omits an essential element in the training of that pupil.

General Aims

The main objectives to be kept in mind in planning instruction in physics are:

1. **The cultivation of desirable habits of mind.** The truly scientific mind has developed habits of fine discrimination, of keen observation, of accurately comparing and judging values, of weighing evidence and thus avoiding snap-judgments, of not going beyond the evidence into sweeping conclusions and of open-mindedness, modesty and truthfulness. It knows that "truth once discovered always remains truth," and that evolution, growth, not revolution is true progress.

The cultivation of such habits of mind through the proper teaching of science in the high school is of infinitely more value than the amassing of mere information. By such means alone can the public mind be freed from superstition and the too ready acceptance of half-truths and falsehoods.

2. **The utilization of the cultural values of the study of physics.** Too frequently the fact that science deals with the material elements and processes of the world is interpreted as meaning that science has nothing to contribute to the education of youth except immediately usable information. Science is even richer in cultural and disciplinary values than in immediate, practical applications. The humanities deal with the reaction of mankind to emotional stimuli. They take into account the variableness and uncertainty of human conduct and response. Science deals with fixed laws and the absolute dependence of effect upon cause. The complete education of the individual requires that he be given experience in dealing with data of both types.

In addition, the history of the contribution of the physical sciences to civilization and the study of the lives and work of great physicists afford a cultural training comparable with that resulting from the study of other phases of history or of the contribution of leaders in other lines of human thought.

3. **A knowledge of the important facts and laws of physical science** necessary to an intelligent understanding of present environment, and participation in and growth with the social organism of which the pupil is a part.

Organization

In the outline here presented, the committee has endeavored to offer concrete suggestions for effecting changes in the organization and methods of physics study which, in their judgment, are desirable.

The correction of the present over-crowding in physics courses. Thoroughness, if it signifies mastery, can not be too greatly desired or too strongly recommended, but that so-called thoroughness which overloads the physics course of the high school until the outcomes can be but little more than partly comprehended information is opposed to the basal values of science education.

The cultural and disciplinary values of physics study can not be realized by proceeding hastily from topic to topic. They depend upon the mastery of fundamental concepts, laws and principles and upon the growth in mental power which occurs when a definite and vigorous reaction is obtained from the student. Obviously, therefore, the teacher who overcrowds his course in physics thereby defeats the chief purposes of its study. Far more desirable results will be obtained by attempting only so much subject matter as can be truly mastered.

The committee has listed seven major divisions of physics as teaching units, and has endeavored to include in the outline only those fundamental portions of each unit which it believes may be properly taught in the time usually available for the subject. In this respect, the outline is submitted as a guide in the selection of material from the particular textbook in use. The committee has carefully considered the time distribution and recommends that each unit be given all of the time allotted to it.

Procedure

1. **A large use of local material and interests.** The school plant and the locality in which the school is situated offer most valuable facilities for the practical study of physical facts and laws. Both boys and girls can profitably study the application of the principles of physics to the devices and operations of the home, and in other lines in which they have a natural interest. There should always be provision for diversity of interest. The same suggestion may be applied in developing courses adapted especially to pupils in agricultural communities, in cities, and to localities in which there is a special industry.

2. **The reduction of the time given to purely mathematical ideas and computations.** It is not the primary function of the physics teacher to teach mathematics. Computation should be used as a means of teaching quantitative relations in physical laws, or of fixing in mind applications of physical facts and laws. Complicated numerical work should be avoided as time-consuming, and as tending to conceal the relationships that it is desired to teach.

3. **The introduction of more group experimentation.** The committee believes that what has sometimes been termed the "lecture-laboratory method" should be more frequently used. By this method the entire class, under guidance of the teacher, conducts an experimental study with one set of equipment. Each pupil then writes an individual laboratory report. One advantage of this method is that it permits the study of large-type apparatus which could not be duplicated for each pupil. This method also retains many of the advantages of the lecture-demonstration method with its better focus and saving of time, and of the pupil experimentation method with its training in manipulation of apparatus and its demand for individual initiative.

In suggesting the use of this method we do not imply that the pupils should not have the opportunity for individual experimentation and inquiry. Such tests of detailed facts and laws will grow out of the larger group studies, as a means of finding answers to special questions that will arise. The committee calls attention to the special adaptability of the lecture-laboratory method to the teaching of physics in small high schools. Physics instruction in these schools is often limited or omitted because of a feeling that effective teaching requires an elaborate laboratory equipment. The farm or small community boy or girl has special need for a practical and concrete training in physics. By the group method, the resourceful teacher can secure commendable results with a few accessories in the way of measuring instruments and a limited supply of practical equipment collected by the pupils or constructed at small cost in local shops.

Adaptability and Minimum Work

The experienced teacher appreciates the fact that any outline requires adaptation to the particular problems of class and individualized instruction. For meeting college entrance examinations, as at present given, this outline will need amplification in certain parts, but for an intelligent understanding of the important laws and principles of physics and the general aims set forth in the introduction, it is more than adequate. For community needs and specialized courses, the outline probably needs greater emphasis in certain directions and less in other; as for example, the subject of mechanics probably does not need, for many pupils, as much detail as is indicated, but for those expecting to go on in the technological fields it is minimum as given. For a rounded general course the committee recommends that the time limits be adhered to rather closely. Any considerable deviation from the suggested periods and topics should require justification based on an intimate knowledge, on the part of the teacher, of the community, class and individual pupil needs. The committee believes that the outline is sufficiently minimum and flexible to be workable in the hands of an experienced teacher. Specific methods of presentation are not suggested beyond the hope that the psychological approach will recommend itself to all teachers. See Procedure in the introduction.

As to minimum work, emphasis as here suggested may be helpful:

In UNIT I—Emphasis should be placed on a clear understanding of: Force; Mass; Weight; Gravity; Motion; Units of Measurement: absolute and gravitational; Work: Newton's Laws; Composition and Resolution of Forces.

All of UNIT II is important.

In UNIT III—If necessary, merely discuss: coefficient of linear expansion, cubical expansion, saturated vapors (if work on steam engine is not greatly emphasized).

In UNIT IV—For slower pupils working on the pendulum, determine the period only for greater individual adaptation, more stress could be placed on the study of musical instruments.

In UNIT V—Emphasize illumination in the home. Do not over-emphasize problems of construction in optics.

In UNIT VI—If apparatus is wanting, some experiments may need to be merely demonstrated.

Equipment

Physics cannot be taught satisfactorily without facilities for lecture demonstrations and laboratory work. An expensive laboratory equipment, however, is not a necessity. When the school

building does not provide a lecture room and laboratory of the accepted type, a well-lighted room with tables may serve for both purposes. Running water, a source of electric current and some means of heating are essential, as is also a supply of measuring instruments and accessories. Where it is not possible to obtain the large number of articles suggested in catalogues and textbooks, a resourceful teacher will be able to assemble a very effective equipment from local sources with the help of the pupils. Much of this material should be of a commercial type. Although precise measurements in the determination of physical constants cannot be attempted with such apparatus, it will serve admirably as a means of demonstrating physical facts and laws, and will tend to establish the habit of applying the knowledge acquired in the class room and laboratory to the interpretation of the phenomena observed in the daily life of the pupil.

Student Observations and Note Books

Pupils should be required to keep note books and to write reports of laboratory experiments, whether of the individual or of the group type. The committee recommends that each specific objective be brought out as a problem to be solved following a brief class discussion before the experimental work is undertaken. The notebook report should be concerned mainly with the data secured, the computation of the final results and a discussion of the conclusions which follow from the results obtained.

Following is a list of apparatus for Physics suggested in Bulletin 27, No. 22, Laboratory Layouts for the High School Sciences, by A. C. Monahan, Office of Education, Washington, D. C.

General Equipment: A manual training bench; sources of electrical current; a switchboard; laboratory clock; a mercurial barometer; rotator; air pump; static machine; optical disk; alternating current apparatus.

List A—Apparatus for Students' Experiments

24 meter sticks, English and metric.
24 rulers, maple, English and metric, 30 cm.
3 vernier calipers.
3 micrometer calipers.
12 trip scales, with agate bearings.
12 sets weights, iron, slotted, with holder, 10-500 g.
3 sets specific gravity metal cylinders.
3 wooden cylinders, waterproofed.
3 wood blocks, rectangular, waterproofed.
3 wooden blocks, rectangular, loaded.
3 lead sinkers, about 175 g.
3 plumb bobs.
6 pressure gages.
30 ft. rubber tubing, ¼ inch.
12 overflow cans.
12 catch buckets.
4 Boyle's law apparatus, J tube.
24 prisms, hardwood for fulcrum.
4 hydrometers, for light liquids.
4 hydrometers, for heavy liquids.
24 spring balances, 2,000 g. 64 oz.
6 composition of Force boards.
12 pulleys, single, bakelite.
12 pulleys, double, bakelite.
12 pulleys, triple, bakelite.
3 center of gravity blocks.
6 inclined planes, with graduated arc.
6 Hall's cars, for inclined plane.
3 wheel and axle, aluminum.
12 resonance tubes, glass, 4 by 45 cm.
12 thermometers,—10 to 110° C.
12 air thermometer bulbs, 50 mm.
3 planes, grooved, with steel ball and powder
12 steam generators.
12 calorimeters, nickeled brass, 75 by 125 mm.
12 tuning forks, C, 128.
12 tuning forks, C, 256.
2 vibrographs (fork-rating apparatus).
2 tuning forks, for above.
24 mirrors, plane, 4 by 15 cm.
12 refraction plates, glass, 7 by 7 cm. by 6 mm.
12 refraction plates, triangular, 75 mm. faces by 7 mm.
6 optical benches.
12 lenses, convex, 15 cm. focus.
12 lenses, convex, 10 cm. focus.
12 prisms, equilateral, 75 mm. with 28 mm. faces.
3 lodestones.
6 rods, soft steel for magnetizing in earth's field, 6 mm. by 10 cm.
24 bar magnets, 1 by 1 by 15 cm.
12 magnets, U-shape.
24 magnet compasses, 25 mm.
24 dry cells.
12 voltaic cells, students' single fluid.
3 dip needles.
6 galvanoscopes.
6 bot. iron filings (4 oz.) in shakers.
12 electromagnets.
2 telegraph sounders, 4 ohm.
2 telegraph keys.
2 telegraph relays.
12 electric bells, 2½-in. gong.
2 electrolysis apparatus, battery-jar type.
2 storage cells.
4 resistance boxes, standard, 0.1-111 ohms.
6 D'Arsonval galvanometers, jeweled pivots.
4 ammeters, DC, double range, 0-3 and 0-30 amps.
4 voltmeters, DC, 0-150 v. in 1 v. divisions and 15 v. in 0.01 volt divisions.
4 wheatstone bridges.
2 commutators, simple form.
24 coils of wire, DC, 40 turns No. 24.
2 speed indicators.
6 electroscopes.
6 Leyden jars, pint.
6 friction rods, vulcanite, 25 cm.
6 friction rods, glass, 25 cm.
48 pith balls.
6 cat skins, half.
3 fish lines (card).
4 telephone transmitters.
4 telephone receivers.
12 ringstands, 3-ring.
12 test-tube clamps.
24 double connectors, brass.
24 jars, battery, 150 by 200 mm.
24 marbles, glass, ¾-inch.
24 thistle tubes, 30 cm. stem.
12 barometer tubes, thick wall, 80 cm.
3 ball and ring.
3 linear expansion apparatus, lever type.
24 candles, paraffin, 12's.
Approximate cost, $1,150.

List B—Tools, Stocks, and Supplies

6 knife switches, single throw, single pole.
6 knife switches, double throw, double pole.
24 asbestos squares, 6 in.
2 sets cork-borers, 1-3.
24 wire gauze squares, 5 inch.
24 pinchcocks, screw compression.
6 spls. copper wire, DCC, No. 24 (4 oz. spls.).
6 spls. copper wire, DCC, No. 28 (4 oz. spls.).
3 lbs. copper annunciator wire, No. 18.
3 spls. German silver wire, bare, No. 28 (4 oz. spls.).
3 spls. piano wire, No. 2.
3 rolls piano wire, No. 9 (4 oz. roll.).
3 spls. piano wire, No. 7.
3 spls. piano wire, No. 5.
1 spl. fuse wire, ½ ampere.
1 spl. fuse wire, 1 ampere.
1 spl. fuse wire, 2 ampere.
1 spl. fuse wire, 5 ampere.
6 files, round, 6 inch.
6 files, triangular, 6 inch.
2 wrenches, monkey, 8 inch.
3 pliers, side cutting, 5 inch.
3 pliers, round nose, 6 inch.
3 screw drivers, small, 4 inch.
3 screw drivers, large, 8 inch.
3 hammers, claw, 7½ oz.
3 snips, metal, 2½ inch cut.
3 pkgs. corks, asst. 0-11 (144).
12 graduates, cylindrical, 100 cc.
6 graduates, cylindrical, 250 cc.
3 lbs. rubber stoppers, 2 hole, 0-.0 asstd.
36 ft. rubber tubing, $\frac{3}{16}$ inch.
9 lbs. glass tubing, 5 mm.
6 spls. spring brass wire, No. 22.
6 spls. spring brass wire, No. 28.
3 soldering sets.
24 bottles, glass stopper, for reagents, 4 oz.
12 lamp chimneys, students'.
12 hydrometer jars, 15x2 inches.
9 flasks, 250 cc., Pyrex.
12 funnels, 90 mm.
3 lbs. thermometer tubing.
3 sq. ft. copper sheets, No. 20.
3 sq. ft. lead sheet, 1/16 in. thick.
3 sq. ft. zinc sheet, 1/16 in. thick.
27 lbs. acid, sulphuric, com'l.
15 lbs. copper sulphate, cryst., tech.
6 lbs. ether, sulphuric, U. S. P.
9 lbs. mercury.
6 lbs. nickel ammonium sulphate, com'l.
6 lbs. paraffin, hard.
15 lbs. potassium bichromate.
6 lbs. sulphur, roll.
3 lbs. vaseline (petrolatum), yellow.
6 lbs. zinc sulphate.
12 Bunsen burners.
Approximate cost, $180.

List C—Classroom Demonstration Apparatus

(Suggested minimum list)

2 cohesion plates, glass.
1 capillary tube, set of 7, mounted.
1 osmometer.
1 membrane.
1 table rotator (see motor-rotator, List D)
1 centrifugal hoop.
1 acoustic and color disk.
1 second law of motion apparatus.
1 lift pump, glass model.
1 force pump, glass model.
1 Pascal's vase, with metallic diaphragm.
1 air pump and plate on one base.
1 bell jar, 2 gallon.
1 jar vacuum wax.
1 seven-in-one apparatus (spirometer).
1 barometer tube with mercury well.
1 barometer, aneroid.
1 barometer, mercurial, Fortin principle.
1 compound bar.
1 steam engine model.
1 electrophorus.
1 electromagnet, lifting.
1 induction coil, demonstration, 6 mm.
1 wire spiral, showing wave motion.
1 organ pipe with movable piston.
1 optical disk.
1 disk illuminator.
1 hydraulic press, glass model.
1 seconds pendulum, with mercury contact.
1 sonometer.
1 motor, shunt wound, 110 v. D. C., m. h. p.
1 motor brake and mounting.
Approximate cost, $260.

List D—Additional List of Demonstration Apparatus

(Selections should be made from this list as needs require and funds permit)

1 elasticity of flexure apparatus, contact method.
1 torsion apparatus.
1 motor-rotator, 110-v. A. C. motor.
1 centrifugal globe.
1 Arago's magnetic rotation apparatus.
1 gyroscope (medium size).
1 sand pendulum.
1 Magdeburg hemisphere.
1 water motor, demonstration.
1 Boyle's law apparatus.
1 rotary blower, electric, 110-v. A. C.
1 rotary vacuum pump.
1 vacuum tube.
1 bell in vacuo.
1 guinea and feather tube.
1 manometer for air pump.
1 maximum density of water apparatus.
1 radiometer.
1 mechanical equivalent of heat tube.
1 gas engine, model.
1 static machine.
1 Leyden jar, dissectible.
1 discharger.
1 set Geissler tubes (6) 15 cm. long.
1 contracting helix.
1 earth induction coil.
1 induction coil, 1 in. spark.
1 alternating current apparatus.
1 galvanometer, lecture table.
1 galvano-volt-ammeter (six-in-one).
1 lamp board resistance, 5 lamp.
1 electrolysis apparatus, improved, Hoffman.
1 sympathetic vibrating bar.
1 pr. singing tubes, Knipp's small form.
1 refraction tank for use with optical disk.
Approximate cost, $650.

Summary

List A—Individual apparatus for 24 students, $1,000.
List B—Tools, stock and supplies, $165.
List C—Classroom demonstration apparatus, $245.
List D—Additional list of demonstration apparatus, $550.
Total,
Annual replacements, $150 to $250.

If all of the above items for Physics were purchased at one time a considerable reduction should result.

Unit I.

Mechanics of Solids

TIME:—APPROXIMATELY 8 WEEKS

Specific Objectives and Desirable Outcomes

1. **A force is required to change the state of rest or motion of a body.**

   A qualitative understanding of inertia.

2. **Forces exist in equal and opposite pairs.**

   A force is the action (push or pull) of one body, A. upon a second body, B. Body B always offers a reaction. The action and the reaction are always equal, opposite, and simultaneous. The reaction is a force or is measurable in units of force.

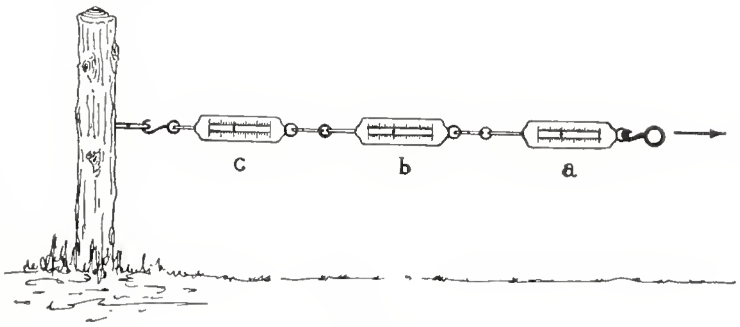

Fig. I

3. **A force may produce or tend to produce motion in a straight path (translation) or tend to produce rotation about an axis (moment or torque).**

   The measure of a moment of force. Moment arm—how measured and why. Common units of moment or torque—as pound-inch, pound-foot, gram-centimeter, etc.
   Direction of a moment.

4. **The effect of non-parallel forces acting simultaneously at a point.**

   Resultant, Equilibrant. Quantitative determination of resultant by the graphical method. A system of non-parallel forces acting at a point tend to produce translatory motion only.

5. **How to resolve a force into its components.**

   Use of the graphical method in determining quantitatively the components of a given force. A force may be replaced by its components or the components may be replaced by the resultant force.

6. **Gravity or weight acts like a single force applied at a point called "Center of Gravity."**

   Definition of Center of Gravity. Center of gravity of uniform bodies. Location of the center of gravity of common areas. Stability.

Content and Suggested Activities

Give examples showing how state of rest or motion is changed.

Using spring balances to measure the forces:
(1) Illustrate the impossibility of pulling 10 pounds on an unattached cord. (2) Account for the readings of balances (a) (b) (c) when a pull is applied by the hand to (a).

Discuss the forces acting in such common cases as a book resting on a table; a post supporting a beam (forces at top and bottom of post); a sled being drawn over ice, etc.

Illustrate by any simple devices (a) translatory motion; (b) rotatory motion. By means of a uniform rod supported at its center and convenient weights, demonstrate moment of force and the factors upon which its value depends.

Teach the representation of forces by lines.
Demonstrate the principles known as the Parallelogram of Forces.

Determine by application of the Parallelogram of Forces first the Horizontal and vertical components of a given oblique force (square paper may be used to advantage)—then the components at any desired angles with the given force.

Determine the centers of gravity of a uniform rod, of a rod made up of different materials or weighted and of a lamina; support each at its center of gravity and compare in each case the pressure on the support with the total weight of the body.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

CONTENT AND SUGGESTED ACTIVITIES

Position assumed by suspended bodies. The component of the weight of a body on a slope which tends to cause the body to roll or slide down the slope, and the component which gives pressure perpendicular to the slope. Force required to haul a body up a slope.

7. **The effects of forces acting in parallel directions.**

Resultant of parallel forces—equals their algebraic sum and acts at a point giving a moment equal to the algebraic sum of the moments of the forces. Equilibrant—equal to the resultant and acts in the opposite direction at the same point.

Set up a typical system of parallel forces and show that such forces tend to produce both (a) translation, and (b) rotation.

8. **The concept of forces in equilibrium.**

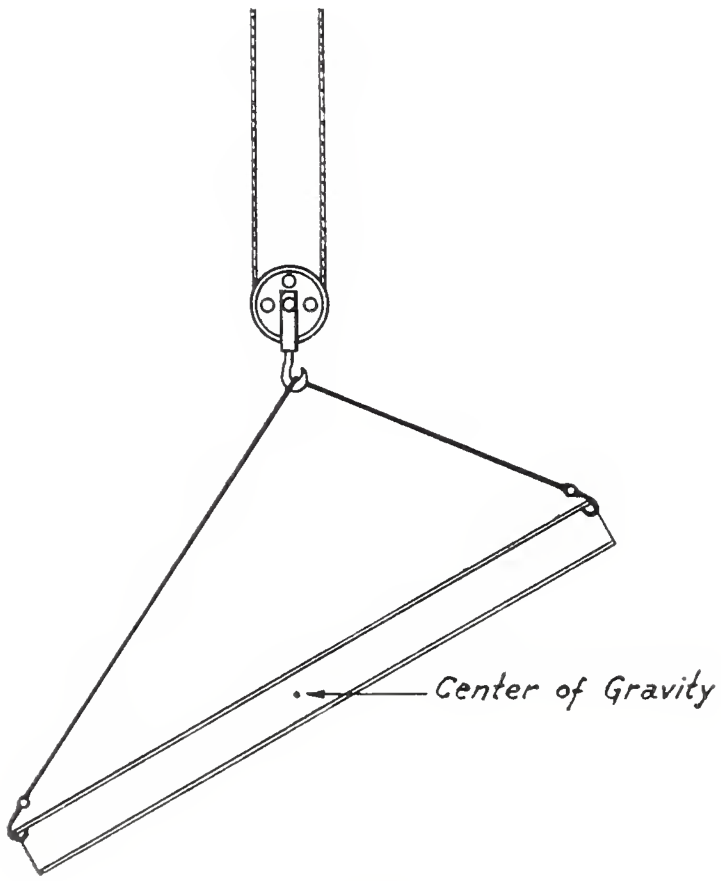

Fig. II

Non-parallel forces acting at a point tend to produce translation only, therefore to be in equilibrium such a system must have a total resultant of zero. With three non-parallel forces acting, the resultant of any two is equal and opposite to the third force.

Parallel forces tend to produce both translation and rotation. Therefore to be in equilibrium: (a) The algebraic sum of the forces must be zero (no translation); and (b) the algebraic sum of the moments of all forces must be zero (no rotation). Forces are in equilibrium when their effects are balanced.

1. Study such simple systems of nonparallel forces as equilibrium as illustrated by the suspended body in Fig. II and the simple truss of Fig. III. In Fig. II, given the weight of the suspended body, measure the necessary angles and determine the tensions in the supporting cords.

In Fig. III, given the lead at L, determine the tension in the tie CL and the compression in the member AB.

Check the solution of Fig. II and Fig. III by using spring balances to measure the computed forces.

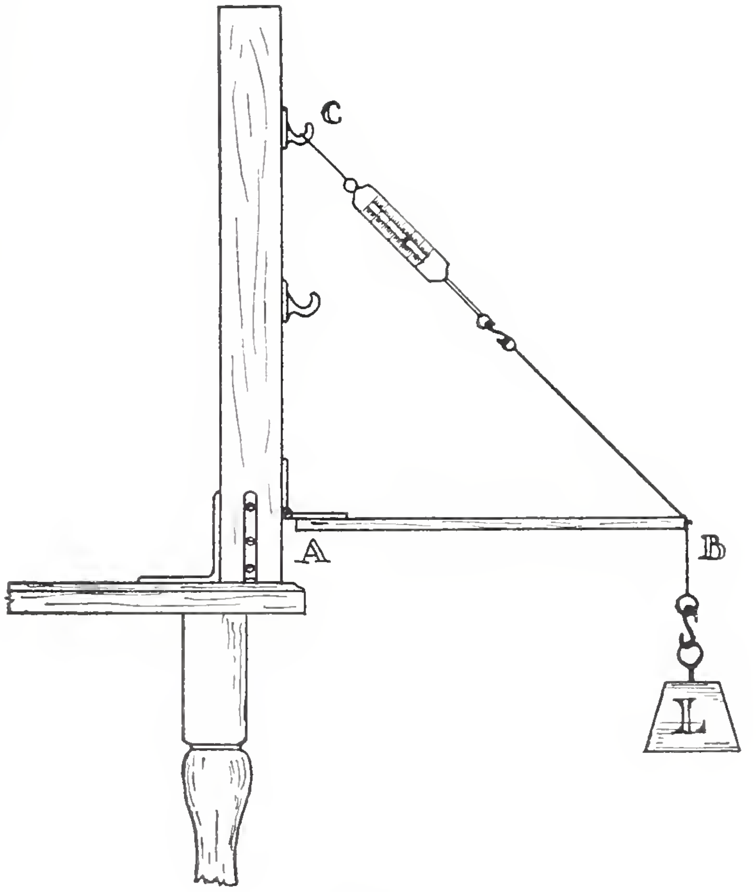

Fig. III

2. Study such a typical system of parallel forces in equilibrium as is illustrated by the beam or girder shown in Figs. IV and IV-A. Consider the weight of the beam and the loads L_1 and L_2 and determine the pressure on the supports at A and B, first by considering the upward reaction at B as the unknown force and writing the equation of moments about an axis at A, then by a similar equation about an axis at B. Check by comparing the sum of the upward reaction at A and B with the sum of the downward forces.

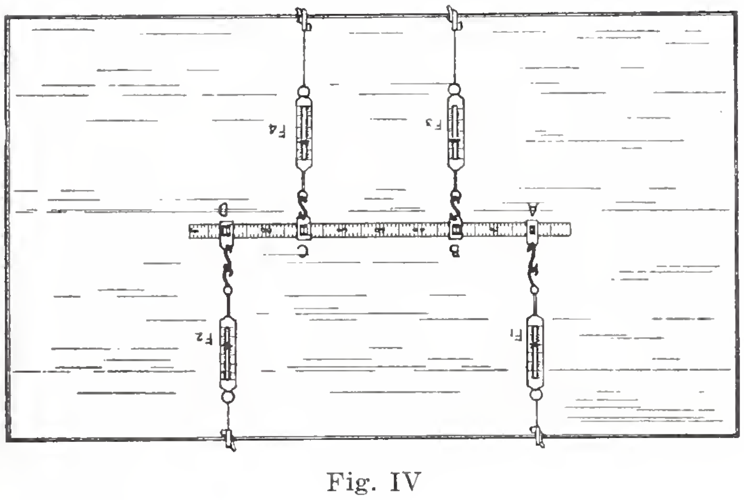

Fig. IV

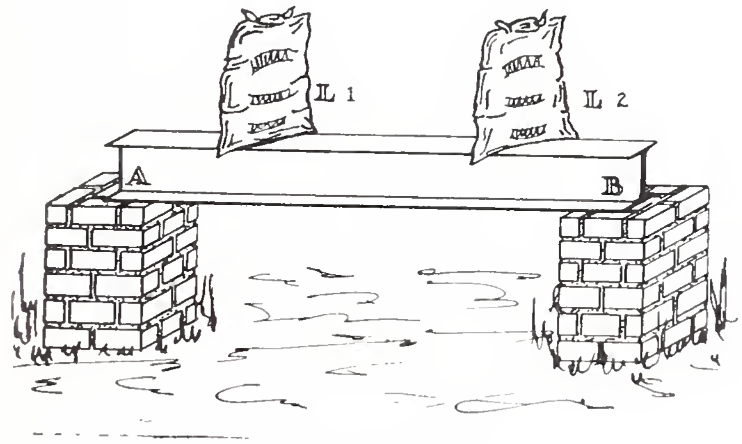

Fig. IV-A

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES

9. **The effect of forces not in equilibrium—the starting and stopping of bodies.**

Bodies acted upon by a system of balanced forces remain at rest, or in uniform motion, along a straight path, or continue to rotate with uniform speed about a fixed axis. Where the system of forces is unbalanced, the body gains velocity, loses velocity or changes the direction of its motion.
A definition of acceleration.

Neglecting air resistance, all bodies fall with the same acceleration, approximately 32 ft./sec.^{2}. *The symbol g represents acceleration when acceleration is due to gravity.*

Distinction between the weight of a body and its mass. When a body is acted upon by an unbalanced force, the acceleration imparted is directly proportional to the force and inversely proportional to the mass of the body. Quantitatively this law may be expressed by the equation $Force = \frac{Weight}{g} \times acceleration$, *where force and weight are expressed in the same units, e. g. pounds, and g and acceleration in the same units, e. g., ft./sec.*^{2}.

10. **Work is done in the production of motion or heat.**

11. **The amount of work done is measured by the product, —force applied times the distance through which it is applied. The units of work.**

Displacement is necessary if work is done.
The force must be measured in the same direction as the displacement. Measure of the work in lifting a body vertically; in sliding a body up an incline; in moving a body along a horizontal surface by a force that is not horizontal. A unit of work is specified by giving the unit of displacement and the unit of force, e. g., foot-pound, inch-pound, centimeter-gram. Compare units of moment.

12. **The work done BY a machine (OUTPUT) is always less than the work done on the machine (INPUT). Losses due to friction.**

For a frictionless machine, effort x distance through which it is applied=load x distance load is lifted, or input=output. For any actual machine, effort x distance through which it is applied=output+work done in overcoming friction.

13. **The common means of reducing and of increasing friction.**

The necessity for proper lubrication of machinery.

CONTENT AND SUGGESTED ACTIVITIES

Observe the motion of a falling body, a body thrown vertically upward and a car or ball made to run down a slope. Increase the slope in the last mentioned case, and note the effect. Compare qualitatively the forces necessary to start a heavy ball and a light ball rolling along a level surface. Compare similarly the forces required to stop them.

Discuss the starting and stopping of automobiles.

Demonstrate by simple apparatus, as for example, a device for hoisting a weight and a simple prony brake, etc.

Determine the two factors, force and distance through which it acts involved in several common examples of work.

(*Note to the teacher.* A few simple machines as block and tackle, wheel and axle, simple belt drive, gear train, etc., will be of great value in teaching Objectives 10-15. These should be of commercial type and not the small, almost frictionless special models often employed in physics teaching. Such simple devices may usually be put together in the school shops or may be built to order at small cost. The effort and load may be applied by scale pans and weights suspended from cords winding on drums attached to the gear or pulley shafts. In operation, the effort should be increased until when the machine is started, it will continue to lift the load *with uniform speed.*)
Using the equipment suggested in the preceding note, determine input and output for a simple machine at any convenient load.

If time permits, an experimental test of the friction of steel on cast iron, bronze and babbitt metal (dry) will prove valuable; a comparison of the friction between metal surfaces when dry and when well lubricated; and of cast

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
	iron on leather belting when clean and when coated with a belt dressing. If lack of time prevents actual tests, a comparison should be made of hand-book data on the friction of such surfaces in contact. Examine and discuss typical ball and roller bearings. Discuss any available data of the relation of friction, especially air friction, to speed.
14. The efficiency of a machine is the ratio of the output to the input. *The advantages of operating a machine at highest efficiency, non-reversible machines, or machines having an efficiency of less than 50%, e. g., the screw and the chain hoist.*	Using a simple machine (see note to Objective 10), determine its input, output and efficiency for various loads. Plot the curve showing the relation of efficiency to the load on the machine. Use efficiency expressed as a per-cent as ordinates.
15. The mechanical advantage of a machine is the number of times the machine multiplies the force applied to it. Actual and ideal advantage. *The ideal mechanical advantage of a machine is constant and depends only on the design. The actual mechanical advantage of a machine varies with its conditions, lubrication, etc.*	Determine the *ideal* mechanical advantage of such devices as block and tackle, the lever, and the wheel and axle from observation of their dimensions and their arrangement for use. Determine their *actual* mechanical advantage at a given load from a test as in Objective 14.
16. The POWER of a machine is the rate at which it can do work. The units of power. *Power may be expressed in any units which specify the work done and the time in which it is performed. Meaning of the expression "foot-pound per second." Meaning and origin of the term "horsepower." The horsepower rating of automobiles.*	Apply a simple prony brake to the belt pulley of a water motor, small gasoline engine, or small electric motor and determine the power delivered. Where such equipment is not available, a hand driven device may be used.
17. A concept of energy. *Work is the act of transferring energy. Energy is expressed in the same units as work. Distinction between work, power and energy.*	Discuss the various sources and kinds of energy.
18. The mechanical energy of a body may be due to: (a) A strain to which it has been subjected (Potential Energy). (b) Gravity (Potential Energy). (c) The motion of the body (Kinetic Energy). *The measure of the potential energy of a body. The measure of the Kinetic energy of a body. The transformation of energy. Conservation of energy. Available energy.*	Discuss the energy of such common cases as: (a) A coiled clock spring. (b) The water stored in an elevated tank or reservoir. (c) A falling weight. (d) A stream of water. Demonstrate the capacity to do work of one or more of these.
19. Molecular Forces. (May be deferred until gases are studied.) *The Kinetic theory of matter: Cohesion, Adhesion, Elasticity. Elastic limit and breaking strength of solids. Diffusion. Hooke's Law.*	Apply the Kinetic theory of matter to the distinction between solids, liquids, and gases. Compare the molecular forces in each. Demonstrate cohesion in liquids. Observe the stretch and elastic properties of a wire under slowly increased tension. Measure its tensile strength.

UNIT II.

Mechanics of Fluids

TIME:—APPROXIMATELY 3 WEEKS

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
1. **A fluid exerts equal forces in all directions at any given point below its surface.** *Pressure*$=\frac{force}{area}$ *Force=pressure* x *area* *Pressures are expressed in lbs. per sq. in. or gms. per sq. cm.*	Distinguish between force and pressure. Demonstrations showing the forces on the bottom and sides of vessel containing water. Upward forces of liquids. Simple apparatus such as Pascal's vases may be used for such demonstrations.
2. **The pressure in a fluid at any point below the surface is dependent only upon the depth and density of the fluid.** *1. The ability to solve problems dealing with fluid pressures.* *2. Knowledge of some of the practical applications of fluid forces such as diving bells, submarines, city water systems, etc.* *3. A knowledge of the construction and uses of the barometer.*	Demonstrate by means of Pascal's vases that the pressure exerted by a fluid: Is proportional to the depth. Independent of the shape of the containing vessel. Depends on the weight per unit volume (d) of the liquid. Is equal to the weight of a column of liquid with a base one unit square and a height equal to the depth of the liquid. Solution of numerical problems involving Pressure = h x d Force = a x h x d A study of water pressure In home or school In water tanks Discussion of the construction of dams, water tanks, submarines. Construct and explain the action of a mercury barometer. Discussion and demonstrate the aneroid barometer.
3. **A knowledge of the principle of fluid pumps.**	Recall that the pressure exerted upon gases and liquids is distributed in obedience to Pascal's law. Demonstrate a simple suction pump. Demonstrate a force pump with an air dome. Demonstrate vacuum pump and also show how it can be used as an air compressor. Allied supplementary activities. A study of water turbines, rams, siphon, pressure gauges, centrifugal pumps, etc.
4. **A pressure applied to a confined fluid is transmitted undiminished equally to every unit area that the fluid touches.** *Knowledge of the many practical applications of Pascal's Law.*	Review the distinction between force and pressure. Demonstration by teacher using model of hydraulic press or hydraulic jack. Solution of simple numerical problems based on hydraulic jack or hydraulic press. Blaise Pascal 1623-1662. His contribution to physics.
5. **A working concept of density. Specific gravity as distinguished from density.** *Ability to solve problems involving sp. g. and density. Use of the hydrometer.*	Measure and weigh a regular solid. Calculate the weight of a unit volume. Define density as the weight per unit volume. Demonstrate that the density of an irregular solid can be found by the displacement of water. Recall Archimedes principle. Define specific gravity. Solve numerical problems involving both density and specific gravity of solids and liquids heavier and lighter than water.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	Specific gravity and density of gases. Density of air, hydrogen and helium. Demonstrate hydrometer. Discuss its practical uses, for example: Care of batteries.
6. **The apparent loss of weight of a body in a fluid is equal to the weight of the fluid displaced.** *A knowledge of why ships float. The principle of balloons and dirigibles.*	Tell the story of Archimedes and Hiero. Recall that objects may be lifted more easily when submerged in water. Demonstrate the buoyant effect of a liquid by weighing a solid in air and then in water then in liquids lighter and heavier than water. Demonstrate by means of an overflow can that a floating body displaces its own weight of a liquid. Solve simple numerical problems involving Archimedes principle. The construction of ships and submarines and dry docks. Archimedes principle applied to gases, balloons, dirigibles, etc.
7. **The Volume of a gas at constant temperature varies inversely with the pressure.** *Knowledge of methods of measuring gas pressure and its importance in our daily life.*	Demonstrate Boyles Law apparatus to class. Show that $\frac{V}{V^1} = \frac{P^1}{P}$ or $PV = P^1V^1$. Recall the principle of the mercury barometer and show that it is really a pressure gauge. Discussion of mercury manometer and other types of pressure gauges. Solution of problems involving Boyles Law. Discussion of practical phases of Boyles Law—e. g.—Condensers in steam turbines, gas used for cooking and heating, etc.

UNIT III.

Heat

TIME:—APPROXIMATELY 7 WEEKS

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
1. **Practically all substances expand when their temperature is raised.** **Solids** *Realization of the importance of expansion in nature and industry.*	Recall experiences of increased bulk of solids, liquids, gases when heated. (Qualitative demonstrations if experiences are too limited.) Determination of coefficient of linear expansion of two metals. Problems involving the use of tables of linear expansion. Discuss cubical expansion. Discuss importance of expansion to the engineer, in the home, in the unequal heating of the earth's surface.
Liquids	Compare coefficients of expansion of solids and liquids.
Gases *Comparison of coefficients of expansion of solids, liquids, gases.*	Recall that the volume change of air is considerable—easily observed by the eye, if the pressure remains constant. Determine roughly the coefficient of expansion of air between zero and 100 deg. C. Consult tables to find the coefficients for other gases.
2. **Principle and use of thermometers.** *Knowledge of the fixed points on both scales.* *Understanding the use and principle of thermometers.* *Ability to change readings from one scale to other. Realization of the importance of having instruments of precision and accuracy.*	Recall or demonstrate the unreliability of bodily sensations of temperature. Study a thermometer. Compare the two common scales. Determination of ice-point (freezing) and steam-point (boiling) on both scales. Discussion of the construction of mercury thermometer. Value of mercury. Study of thermometers for special use, especially the maximum-minimum, clinical, metal. Discussion of temperatures, high and low; of common or interesting events. Construct a graph for comparing Fahrenheit and Centigrade (Celsius) scale readings. Correction of the steam-point of thermometers for standard pressure conditions.
3. **The abnormal expansion of water and its importance in nature.** *Importance of the abnormal behavior of water.*	Observation of the expansion of water as it cools near 4 deg. C. Demonstration of the maximum density of water. Study the curve showing volumes from zero through 4 deg. C. and beyond. Discussion of the maximum density of water and its effect in nature.
4. **Transmission of heat:** **Convection** *Nature and importance of convection currents as a factor in heat distribution and climate.*	Observe the behavior of a liquid heated at one point. Observe any distribution in an air mass enclosed in a box with two openings and heated at one point. Demonstrate the circulation of heated particles in fluids. Explanation of the force that maintains the circulation. Recall experiences with hot air currents in heated rooms. Explanation of temperature differences in a room; of circulation of air related to source of heat; of ventilation problems involved. Discussion of heating building—hot air and hot water.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
Conduction *Relative heat conductivity of various common substances. Understand the principle on which the safe use of the lamp depends. Indirectly: The civic responsibility for conservation of life. Methods and value of heating insulation.*	Investigation of convection currents produced in refrigerators; winds, climatic air currents in and about the tropics; at great altitudes. Discussion of the value of separate air pockets in insulating materials for building. Do the heated particles of a poker circulate the length of the poker? Experiment to discover the relative heat conductivity of a number of substances (metals, water). Compare statements of conductivity of various substances, including gases (air). Study of the Davy Safety lamp; demonstrate the conductivity of wire gauze. Explanation of good and poor conduction in clothing as related to seasons. Common ways of controlling thermal conduction. Discussion of insulators; in building construction; refrigeration; thermos bottle; fireless cooker.
Radiation *Heat distribution by radiation.*	Recall experiences with a fireplace or gas and electric radiators realizing that conduction and convection do not account for all transmission. Demonstrate with radiometer and screens to show straight line transmission. Compare convection and conduction in this respect. Demonstrate convergence of heat rays. Explain how all methods of transmission are retarded in the thermos bottle. Demonstration of good absorbers, good radiators. Explain transmission through glass, absorption by soil and consequent trapping of heat in greenhouse. Explanation of the heating of the earth by the sun.
5. **Heat is a form of molecular kinetic energy.** *Recognition that mass as well as temperature range is a factor.*	Demonstration that two different masses of water having the same temperature have not absorbed the same amount of heat. Does the thermometer measure heat quantity directly?
6. **Measurement of heat.** *Understanding the definition in order to use them. Understanding calorific values.*	Consideration of the factors necessary for measuring heat quantity. Study of standard units—gramcalories and B. T. U. Problems involving use of units. Discussion of some calorific values of common fuels, or foods.
7. **The heat capacities (specific heat) of different common substances.** *Realizing that specific heat is an important property of a substance.*	Recall that water is slower in heating than metals. Determine experimentally the specific heat of several substances. (See method of mixtures below.) Compare substances in specific heat tables. Note specific heat of water. Discussion of the effect of the high specific heat of water on oceanic climates.
8. **Calorimetry exchange of heat between bodies.** *Method of mixtures.* *Realizing that this equation is important in calorimetry.*	Observe the temperature changes obtained by mixing known quantities of water of different but known temperatures. Discussion of heat exchanges in mixtures with as little loss as possible. Discovering how both quantities may be evaluated and equated.

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
9. **The heat required to transform ice at its melting point to water at the same temperature and that must be withdrawn in changing from water at freezing point to ice.** *Knowledge of this value.*	Recall the temperature of melting ice. Compare the value of ice as a cooling agent with an equal weight of water 0 degrees C. Determine the number of calories needed to melt 1 gram of ice at zero degrees C. Investigate the temperature of freezing water; of super-cooled water. Note heat involved in freezing. Consult text for relationship between heat given off in melting ice and in freezing water without change of temperature.
Understanding importance of heat of fusion.	Define heat of fusion. Apply this knowledge in problems such as cooling in a refrigerator, ice blankets; prevention of freezing of vegetables in cellars; moderating effect of lakes on temperature.
Importance of expansion of certain common substances, as ice, cast iron, on solidifying.	Study melting and fusion. Study changes in volume on solidifying. Contractions as a rule, but note exceptions, such as type metal.
10. **The heat required to change water at its boiling point to steam at the same temperature and given out when steam is condensed to water at the same temperature.** *Knowledge of this value.* *Understanding the importance of heat of vaporization.* *Heat is required to change a liquid to a vapor.*	Depression of the freezing point. Regelation. Recall the temperature of pure boiling water, and of its steam under 760 mm. Hg. pressure. Definition of boiling point, in terms of vapor pressure. Recall the relatively long time needed to "boil away" water. Determine the heat of condensation of steam. Problems. Explain how steam heating depends on heat of condensation. Study factors influencing evaporation. Compare boiling and evaporation. Study of ice making and refrigeration.
11. **Humidity.** *Emphasis on the practical importance of attention to relative humidity and realization of importance of knowledge of method of measuring it.* *Knowledge of factors influencing weather. Appreciation of use of science in weather predictions.*	Recall experiences with humidity, summer and winter. Verify guess as to relationship between temperature and saturation of air by consulting tables. Contrast absolute humidity and relative humidity. Determine dew-point. Determine relative humidity from dewpoint considerations. Study wet-and-dry bulb psychrometers, hydrodeik, and tables for determining relative humidity readily. Study the relation between relative humidity and health and comfort and the conservation of fuel. Study conditions for formation of precipitations of various sorts; dew, fog, rain, snow, etc.
12. **Principle and care of the home heating plant.** *Appreciation of the practical importance of the study of heat.*	Examination of home heating plant for construction and understanding operation. Compare various methods of heating—hot air, hot water, steam, direct and indirect heating. Study each system in relation to ventilation, relative humidity, fuel consumption, construction, and principles of operation.
13. **The mechanical equivalent of heat.** *Knowledge of the numerical value for mechanical equivalent of heat.* *Understanding transformation of energy and its importance. Appreciation of fundamental concepts of energy relations.*	Recall experiences showing transformation of work into heat, as from hammering, friction between surfaces boring, collision, compression of gas. Read the account of Joule's work for the first determinations; of Henry Rowland for more recent determinations. Explain the significance of the mechanical equivalent of heat, of conservation of matter and energy, of perpetual motion machines. Sun as source of all energy for earth.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
14. The volume-temperature-pressure relations of a gas. *For all gases at constant pressure, volume is proportional to absolute temperature.*	Recall the coefficient of expansion for all gases. Refer all temperatures to the absolute scale.
Gases. *For all gases at constant volume, the pressure is proportional to the absolute temperature.* $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$	Demonstrate or discuss the construction of a gas thermometer. Understand the principle of the standard hydrogen thermometer. Formulate the law of gas pressure. Solve problem involved. Recall the relation between the volume and the pressure of a gas at constant temperature (Boyle's Law). Formulate the gas equation.
Saturated vapors. **(Optional)**	Observe the pressure of the vapor from ether in (1) a Torricellian vacuum (a) at room temperature (b) at higher temperature (2) effect of a small volume of air admitted to vacuum before the drop of ether. (Let stand for several hours.) Compare the behavior of volume—temperature—pressure—relations of a gas and of a saturated vapor. Discussion of steam pressures.
Steam engine. *Appreciation of the changes due to the industrial revolution.*	Study models of the reciprocating steam engine. Observation of operation on locomotives, if possible. Discussion of boiler steam engine and condensation. Discussion of the importance of this invention in modern life.
Turbines.	Recall the operation of water turbines. Discuss the construction and principles of turbines. Discuss the role of water power in modern life. Conservation. Discuss the efficiency of steam plants.
4-cycle gasoline engine. *Understanding of the essential features of 4-cycle gasoline engine.*	Discussion of the construction of a 4-cycle gasoline engine obtained by observation, visits to machine shops, study of charts, diagrams, pictures. Discuss the power plant of the automobile, and the transmission. Discuss the efficiency of the modern gasoline engine, and its role in modern life.
Diesel engine. *Understanding the attempt to increase efficiency.* *Understanding the operation of the most frequently used engines.* *Appreciation of the "machine" in modern life.*	Discuss the use of the Diesel engine. Compare with other engines.

UNIT IV.

Sound

TIME:—APPROXIMATELY 3 WEEKS

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
1. **Sound has its source in some vibrating body.** *Regular vibrations produce musical sounds.*	Demonstrate using (a) vibrating tuning fork (b) siren
2. **Sound is transmitted by waves through gases, liquids, and solids.** *1. Knowledge that an elastic medium is necessary for sound transmission.* *2. Knowledge that sound travels at the rate of 1087 ft./sec. at O°C.* *3. Knowledge of the nature of compressional waves.*	Discuss motion of sound in air, water, trolley rails, etc. Show that sound will not pass through vacuum (demonstration). Discuss wave length, transverse waves, longitudinal waves, compressions and rarefactions. Use coiled spring to demonstrate compressional wave. Discuss speed of sound variation of speed in different media. Effect upon speed of changes in temperature.
3. **Reflection of sound.** *Knowledge of the cause of echoes. Knowledge of some of the practical applications of sound reflections.*	Compare reflection of sound with rebound of elastic bodies and with the reflection of light. Discuss echoes. Acoustic properties of rooms.
4. **A body vibrating as a whole has a definite frequency.** *The ability to use the relation $v=nl$ in the solution of numerical problems.*	Determine the period of pendulums of different lengths; of a vibrating coiled spring; of a vibrating tuning fork. Discuss the relation $V = nl$.
5. **Loudness of sound depends upon the amplitude of vibration and varies inversely as the squares of the distance from the source.**	Demonstrate with tuning fork and sonometer strings the effect of varying the amplitude. Discuss the reasons for the law of inverse squares as applied to sound waves.
6. **Pitch is determined by frequency.** *Some knowledge of the mechanics of music.*	Demonstrate by means of a siren. Test the pitch of a tuning fork by means of a siren. Discuss the limits of audibility.
7. **A concept of resonance and of forced vibrations.** *One body may impress its vibration rate upon another that has a different natural frequency.* *The amplification of sound by resonance has many practical applications.* *A knowledge of the effects of interference.*	Use familiar experiences to show the effect of a small force periodically applied to a vibrating body—e. g., a child's swing. Discuss such examples of forced vibrations as the sounding boards of musical instruments, loud speakers in radio, vibrations in automobiles, etc. Demonstrate resonance by means of a tuning fork and resonance column. Discuss applications of resonance, e. g., organ pipes and other wind instruments. Demonstrate by tuning forks or sonometer strings the occurrence of interference and beats. Discuss interference. Related activity. Investigate modern radio reception in its relation to beats.
8. **How over tones are produced and how they effect the quality of sound.** *Some knowledge of the reasons for different tone qualities in music.* *An appreciation of the application of scientific principles involved in such everyday affairs as the phonograph and talking motion pictures.*	Discuss the three characteristics of musical sounds, viz.—pitch, loudness and quality. Demonstrate the fundamental and overtone of a vibrating string. Discuss the importance of quality in sound reproductions—e. g.—the "talkies." The analysis of sound by manometric flames and resonators.
9. **Some knowledge of simple musical instruments.** *A knowledge of how pitch variation is obtained in musical instruments.*	Demonstrate the laws of vibrating strings. Use organ pipes, slide trombone, cornet, etc. to illustrate wind instruments. Discuss the phonograph.

UNIT V.

Light

TIME:—APPROXIMATELY 4 WEEKS

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
Light travels in straight lines. *Knowledge of the rectilinear propagation of light.* *Knowledge of theories regarding the nature of light.*	Recall inability to see around corners. Compare sound waves in this respect. Discuss the wave theory of light. Experiment with the pinhole camera. Observe shadows cast by objects between source and screen. Note relationship of size of shadow and distance from the body. Review subject of eclipses and phases of the moon.
The illumination in foot-candles varies directly as the intensity of the source in candle power and inversely as the square of the distance from the source in feet. *Knowledge of the law of inverse squares.* *Intensity of illumination is measured in foot-candles.* *Intensity of the source (luminosity) is measured in candle power.* *Distinction between intensity of the source and the intensity of illumination.* *Appreciation of the responsibility for the conservation of human energy.*	Compare the areas illuminated with varying distances from a constant source of light. Compare the intensity of illumination with increasing areas illuminated. Formulate the law of intensities. Use of the Rumford photometer. Study the light-emitting power of various sources, expressed in candle powers. Discuss standard candle power, standard incandescent lamps, Hefner. Determine by use of the Bunsen photometer the candle power of lamp of unknown power. Discuss the use of the foot-candle meter for direct measurement. Discuss the use of beacons and search lights of high power. Discuss the relationship between industrial production and optimum intensity of illumination for the workers. Consider the safety factor.
Reflection of Light. **Law of reflection.**	Discuss the visibility of luminous and nonluminous bodies. Distinguish between transparent, translucent, and opaque objects. Determine the course of rays reflected from a plane mirror. Discuss diffused and regular reflection. Discuss the use of reflectors.
Requirements for good illumination in the home. *Appreciation of the application of scientific knowledge to health problems.*	Discuss the development of artificial lighting. Discuss the value of large and small units for home and street lighting. Discuss the proper lighting for play and work—absorption by and diffusion from surrounding objects. Discuss the avoidance of glare and the proper protection of the eyes. Value of the indirect system of illumination. Test the best advice about the proper position of a book when reading and the proper placing of lights.
Formation of images by mirrors. *Ability to diagram the course of light rays.* *Knowledge of characteristics of image formed by plane mirror.*	Explain the formation of an image by a plane mirror. Experimentally locate the image formed. Study the characteristics of image—kind, size as compared with the size of the object, location.
Plane Convex Concave *Knowledge of characteristics of images, as formed by different kinds of mirrors. Understanding the mirror formula and size rule.*	Examine curved mirrors—convex and concave. Study image formed by convex mirror as to characteristics. Compare images formed by concave mirror. Construction of diagrams showing paths of rays of light. Compare characteristics of images formed in each case—kind, size, location in reference to mirror and object. Study the use of mirrors in homes, halls, industry, and scientific instruments.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
The effect on light of passing from one medium to another. *Law of refraction. This ratio is always the same for the same two substances, regardless of what the angle of incidence may be.* *Knowledge of the speed of light as a physical constant.*	Observe the apparent position of objects submerged in water of different depths, and observed at various angles. Determine the path of light passing from glass to air and vice versa. Determine the index of refraction. Discuss the paths through plate glass and through triangular prism. Discuss refraction of sunlight. Read accounts of the difficulty of finding the speed of light—Roemer, Michelson.
Lenses cause light rays to converge or diverge. *Knowledge that lenses that are wide in the middle converge the rays of light; lenses that are thin at the middle diverge the rays of light.*	Recall the way in which light is refracted through a prism. Study convex and concave lenses as two prisms each. Study the effect of parallel rays of light passing through the double prisms and through the lenses.
Knowledge of the equation of convex lenses.	Study the images formed by a single converging lens—object placed at varying distances from the lens.
Knowledge of size rule.	Discuss conjugate foci. Construction of diagrams by tracing rays from objects at varying distances from the lens. Compare size of object with image and object distance with image distance. Discuss linear magnification.
Understanding the optical principles applicable to the microscope and the telescope.	Compare the effect of diverging lenses on light. Discuss defects of images formed by lenses—spherical aberration. Discuss the use of lenses. Discuss the construction and principle of a compound microscope. Discuss the construction and operation of an astronomical (refracting) telescope. Discuss some of the largest telescopes in the United States.
Photography. *The uses of the principal parts of the camera.* *The likeness of the eye to the camera.*	Use empty cylindrical cartons (oatmeal) for pin-hole camera. Remove one end and substitute wax paper held in place by rubber bands. In center of opposite end put pin hole giving some attention to smoothness of the edges. Darken all but a portion of one window in the room and study size, intensity and position of image on wax paper when box is held at distances ranging from three to fifteen feet from a conspicuous object placed in the light of the window. Compare results with images found when convex lenses are used. Particularly note that the pin-hole camera is always in focus. Ask pupils to bring cameras to school. Select one of the bellows type and either remove the back and substitute wax paper for screen or use ground glass provided in some models. Direct it toward the illuminated object and note particularly the effect of "stopping down" (approaching pin-hole) upon brightness and sharpness (focus) of image. Discuss fixed-focus cameras as permanently focused upon object as near to camera as will permit distant objects (depths of focus) to have reasonable focus even though several feet back. Explain reasons for wide range of shutter speeds. Distinguish between the focal length of a lens and the "i" of a camera lens. Explain meaning of achromatic and anastigmatic lenses and methods of obtaining these properties by using multiple lenses of different glasses. (See Eastman Kodak Co. booklet "About Lenses")

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
	Discuss motion pictures. Have pupils draw cross-section of eyeball and compare function of iris, crystalline lens and retina with corresponding parts of the camera. Note especially method of focusing a camera and Nature's method in changing curvature of the lens.
9. Some of the principal defects of the eye and how they are corrected. *Care of the sight.*	Limit this study to near and farsightedness. Show on diagrams position of image before and back of the retina and the necessity of using diverging and converging lenses respectively to make corrections.
10. White light can be broken into colors. *The color of light depends upon its wave-length. The spectrum. Colors of objects are determined by selective absorption.*	Substitute a card having a vertical slot in it for the lantern slide in the projection lantern. Carefully direct the beam passing through the slot to a prism and receive the resulting spectrum upon a large white card. Learn order of colors and memorize them. Mne-monic aids—Roy G. Biv or Vibgyor may be found useful.
Defective color vision and its causes. Note—If time permits study Interference of Light and Polarized Light as showing the nature of light waves.	Put a Bunsen flame playing upon a salt-soaked asbestos pad in the lamp house of the lantern and note position of resulting light relative to position of spectrum previously formed. Add colors on the color disc. Contrast dark line, bright line and continuous spectra. Only a spectroscope will satisfactorily demonstrate dark lines. Distinguish spectrum formed by an incandescent body with that obtained from sunlight. Look up Fraunhefer lines. Discuss wave-length and relation to color. Discuss absorption in colored glass and in colored objects. Stare at red electric lamp for about ten seconds and then turn the gaze to a white card. Discuss complementary colors and retinal fatigue. See that the so-called primary colors of light are the complements of the primary colors of pigments. Discuss color photography and three-color printing.

Unit VI.

Electricity and Magnetism

TIME—APPROXIMATELY 10 WEEKS

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
1. **Properties of a magnet and magnetic fields.** *Conception of earth's magnetic fields.* *Law of magnetic attraction and repulsion.* *The magnetic compass.*	Suspend a bar magnet by a thread. Direct attention to (a) the tendency to turn in a N-S position; (b) effect of another magnet brought near; (c) similarity of compass to this suspended magnet. Put bar magnet on table. Cover with paper and sift iron filings on the paper. Study the designs produced by (a) bar magnet; (b) two like poles placed one inch apart; (c) one N and one S pole placed one inch apart. Put piece of soft iron on table and bring compass near. Note reason why either end of the compass is drawn toward the iron. Touch soft iron with bar magnet and explain difference in the behavior of the compass. Remove bar magnet again. Study magnetic induction.
2. **Positive and negative electric charges.** *Attraction and repulsion between electric charges. Condensers, conductors, insulators and dielectrics. Relation between electric charges and electric currents.*	Charge pith ball electroscope using a hard rubber rod rubbed with wool. Study effects produced by nearness of glass rod rubbed with silk, and of the rubber rod. Study the gold-leaf electroscope. Charge a gold-leaf electroscope connected to an insulated plate set in a vertical plane and study increase in capacity when another grounded plate approaches the first one. Charge a leyden jar from an electric machine. Charge condenser plates attached to top of gold-leaf electroscope using several dry cells connected in series.
3. **Fundamental concepts of the electron theory.** **(If this topic has not been studied previously it may be expanded here somewhat).** *All substances are alike in being composed of positive and negative electricity.*	Recall studies in chemistry of molecules and atoms. Introduce the idea of nucleus and of orbit. Emphasize the negative nature of the electron. Discuss the effect of an excess and of a scarcity of electrons. Show meaning of an electric current as moving electrons. Note that markings on instruments, etc., assume an opposite direction of flow than of electrons.
4. **A force of moving electricity (E. M. F.) may be produced by chemical action.** *Simple voltaic cell. Practical applications as in dry cell. Construction of dry cell.*	Start with pure zinc in dilute sulphuric acid, then introduce copper strip and after joining the two, discuss polarization. Next use a strip of commercial zinc and discuss local action on the basis of polarization. Study construction of common dry cell, and mention manganese dioxide as most common depolarizer. Mention non-polarizing cells of the Daniell type.
The principle and construction of storage cells. *The charging, discharging and care of storage batteries.*	Immerse two clean strips of lead having an area of about eight square inches on one side into a 10% H_2SO_4 solution and charge for about 15 minutes using one ampere. Discuss changes observed during the charging process. Discharge cell so formed through small flashlight bulb. Test direction of discharge current and by comparison with direction of charging current, establish rule for proper method of connecting storage cells for charging. Discuss to rapid charging and overcharging. Explain difference between lead type and nickel-iron type of storage cells.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
5. **If a point of higher potential is connected by a conductor to a point of lower potential, an electric current is set up. If the difference of potential is maintained, a continuous current will be produced.** *Potential difference determines the electrical flow between two points. It may be less than, or equal to, but never greater than the total e. m. f. of the circuit.*	Discharge leyden jar through a coil having a soft iron core and show effect upon compass needle. Draw conclusions concerning higher and lower potential. Repeat experiment using dry cell instead of leyden jar. Connect 4 dry cells in series to end of wire having at least 50 ohms resistance. Attach voltmeter to show fall of potential along the wire and differences of current flow (in voltmeter) because of differences of potential along the wire.
6. **The strength of the current in No. 5 is directly proportional to the P. D. and Inversely Proportional to the resistance.** *Ohm's Law in its three forms with a knowledge of the algebra involved.*	Connect four dry cells in series. Using a six volt auto headlight lamp in series with a low reading ammeter observe the current passing through the lamp when connected to two and then to three and then to all four of the dry cells. At each step take voltage readings. Repeat the experiment using a smaller lamp.
7. **Electrical resistance.** *The resistance of a conductor depends directly upon its length and inversely upon the cross section.* *It also depends upon the material used.*	With a voltmeter, an ammeter and dry cells, calculate the resistance of about two meters of No. 24 and also No. 22 G. S. wire. Repeat using four meter lengths. Repeat again using other standard resistance materials such as managanin, constantan and nichrome. Demonstrate and discuss Wheatstone bridge.
8. **Series and parallel circuits.** *In a parallel circuit the voltage is the same for all units. The current flowing in a particular unit, depends upon the resistance of the unit. In a series circuit, all units take the same current, but the voltage at any unit, depends upon its resistance.*	Using the house current, an ammeter, a voltmeter and three lamps of different wattage, arrange the lamps in parallel and test the current and voltage at every possible point. Calculate the resistance and power consumption from observations made. Repeat the experiment arranging the lamps in series. Repeat the experiment again arranging two lamps in series and the third one in parallel with one of them.
9. **When a conductor is carrying an electric current, there is a magnetic field about the conductor, the lines of force in which are concentric circles and the strength of which is proportional to the strength of the current.** *A definite relation exists between a current and a magnetic field. They act at right angles to one another.*	Arrange a No. 20 copper wire vertically through a hole in a plate of glass held in a horizontal plane. Sift iron filings on the glass and send the current from a storage battery through the wire (caution over-heating). Study the diagram produced when the glass is tapped with a pencil while the current flows. Remove the iron filings, and substitute four small magnetic compass needles arranged symmetrically about the wire at a distance of about two inches from it. Note the arrangement of the "N" seeking poles of the compass when the current is turned on. Reverse the current and again make observations. Make the same observations with the strength of the current reduced by a suitable rheostat.
10. **Relation between the direction of the lines of force in the field and the direction of the current.** **The magnetic field about a loop of conductor carrying a current.** *Electromagnets are temporary magnets but they are more useful because they can be controlled.*	Put a magnetic compass on the table and allow it to come to rest. Hold a wire in series with a dry cell and a key over the compass parallel to the direction of the compass. Touch the key and note the direction in which the needle moves. Consider as motion of needle, the motion of the "N" end. Considering the carbon of the dry cell as plus, show the application of the right hand rule for finding the direction of the current by using the fingers and thumb of the right hand. Bend the wire into a complete rectangle and hold one broad face of this rectangle near a compass needle. Establish the rule for finding the "N" pole of an electromagnet using the right hand. Test rules studied using electric bell and small compass. Teach diagram of electric bell.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
11. An E. M. F. is set up in a conductor when it is so moved that it cuts magnetic lines of force. *Relative motion of magnetic field and conductor are necessary for generating e. m. f. mechanically.*	Wind about 500 turns of No. 30 insulated wire on a cardboard cylinder about one and one-half inches in diameter. Connect the ends of the wire to a zero-center galvanometer. Thrust the "N" end of a bar magnet in one end and note the direction of throw of the needle. Note that when the motion of the magnet stops, that the motion of the needle stops also. Withdraw the magnet and note motion of needle while doing so. Repeat the experiment this time moving the coil and holding the magnet stationary.
12. The relation of the direction of the motion, the direction of the lines of force, and the direction of the induced E. M. F. *Thorough mastery of the very useful and important law of Lenz and of the three rules using the right hand.*	Teach Lenz's Law. Show its application in the apparatus used in No. 11. Thrust a wire whose ends are joined to a galvanometer, downward between the poles of a powerful magnet and note the deflection. Study Fleming's rule using the thumb, index finger and center finger of right hand to find the direction of an induced current. Show complete agreement between Lenz's Law and Fleming's rule and incidentally with the other right hand rules.
13. Principle and construction of generator including alternator. *Mechanically produced e. m. f.'s are originally of an alternating form.* *Unidirectional e. m. f.'s are produced by applying a commutator to the shaft of generator. Factors which control the value of the e. m. f. set up by a generator.* *Distinction between the e. m. f. and the terminal voltage of a generator.*	Apply the rules studied in No. 12 to the direction of the induced current in a single loop, hand operated generator. Predict and test the direction of the current each half rotation and bring out the reasons for the growth of the e. m. f. from zero to maximum and decay to zero and for its reversal. Point out the alternating nature of the induced current and distinguish carefully the uses of slip rings and of a commutator. Give attention to the meaning of the adjective "alternating" and "direct" as used electrically. As far as possible, show experimentally the influence upon the e. m. f. of strength of field, speed of rotation and number of conductors. Emphasize the application of Ohm's Law in causing the voltage drop within the armature resulting in different values in e. m. f. and terminal voltage of a generator.
14. When a current is sent through a conductor placed in a magnetic field, a force is set up tending to move the conductor. *As motion can cause an e. m. f. so a current can cause motion.*	Suspend a flexible conductor horizontally and rather loosely so that it will hang within the field of a rather strong magnet. Send a current from a storage cell momentarily through it and note the thrust upward or downward depending upon the direction of current flow.
15. Directional relations of the current, lines of force and force on a conductor. *Motor rule.*	From observations in No. 14 show how by using the center finger, index finger and thumb of the LEFT hand, the direction of thrust may be predicted. Contrast this with the Fleming rule. Show how the right hand rules fall in with the explanation of the motion by the mutual action of the field around the wire due to the current, and the field into which it is put. Diagram these two fields superimposed upon one another, and show how the side of the conductor on which the lines of force become less dense is the one toward which motion will be directed.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
16. Electric motors. *Counter e. m. f. of a motor.* *Necessity for this if a motor is to deliver work.* *Necessity for use of rheostat with motors. Principle and construction of D'Arsonval galvanometers and of commercial ammeters and voltmeters.*	Connect a motor (not over 1/8 H. P.) in series with an ammeter. Note ammeter reading when the switch is first turned on and again after full speed has been reached. Discuss back e. m. f. Increase the load by pressing on the pulley while the motor is running and note the readings. Note that the armature current times the back e. m. f. is the power used in turning the motor armature, therefore, the higher the back e. m. f. coincident with higher speed of the motor, the more nearly does the power used go toward the work done. Make clear that the difference between the applied e. m. f. and the back e. m. f. is the IR required to drive the current through the armature and if this difference is small, the I factor reduces and therefore, the I square R losses are less. Draw the conclusion that a back e. m. f. is a necessary factor for efficiency and regulation. Point out need of substituting for the back e. m. f. while speed is being built up by the use of a starting box. Show that a D'Arsonval galvanometer is in reality a motor and teach the reasons for using resistance in voltmeters and shunts in ammeter.
17. The heating effects of electric currents. Factors which control the amount of heat generated. *Principle and use of fuses.*	Weigh the inner vessel of a calorimeter, put some water in it, and get the weight of the water. Invert a 25 watt carbon lamp in the cup and note the temperature of the calorimeter both before and after heating it with the lamp for about 800 seconds. Review discussion of heat units and make calculations for the constant .24 in the equation for the generation of heat in a conductor. This equation is usually expressed as $H = .24I^2Rt$, but the students often fail to recognize that the I^2R of the formula may just as correctly be expressed as IE or just as watts. Attention to this helps pupils to realize that heat generation means a power expenditure and therefore should be avoided as much as possible except in actual heating devices. Discuss the effect of heat upon the resistance of metal filament and in carbon filament lamps. Show that an increase in current will increase the heat generated and therefore fuses are of value when current values rise dangerously high.
18. Electric lights. *Appreciation of need for vast improvement in electric lamps. They contrast strongly with electromagnetic equipment in point of efficiency.*	Measure the candle-power of a 50 and of a 25 watt carbon lamp an also of a 50 and of a 25 watt tungsten lamp on a photometer and calculate the cost of operation per candle at the local rate for service. Discuss high voltage lamps such as the Cooper-Hewitt and the neon lamps used for advertising. Point out disadvantages of arc lighting but reasons for its continued use in projection work. Give data on efficiency of electric lamps.
19. Electric power. *Watt kilowatt. Watt-hour electrical equivalent of one horsepower.*	Define watt as joule second and in terms of E and I. Define kilowatt and refer to household electric light bills for introducing the terms watt-hour and kilowatt-hour. Teach 746 watts equal a horsepower and show the 3:4 relation of H. P. and Kw.

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
20. The transmission of electric power. **Line losses.** **Advantage of high voltage low current transmission.** *Energy can most conveniently be distributed in the electrical form.*	If possible, have pupils take voltmeter readings at school dynamo and in places as far as possible removed from it. Discuss line drop and account for the heat lost in the line as actual power loss. Discuss costs of transmission lines. Estimate current used at one time in a small town and from reference tables estimate the size of a single conductor which would be required if all of this current were to be carried from the power house to point of delivery. Show how size of conductor can be reduced by readjustment of the factors in the EI formula for watts.
21. The principle, construction and use of transformers. *In distributing electrical energy, voltage-current, relations are frequently altered for economy. The transformer which makes this possible should be regarded as a great achievement.*	Discuss electromagnetic induction. Show how the principle of induction is applied in a dissectible model transformer. Discuss ratio of windings to voltage and inverse ratio to current. Call attention to the transformers placed along city streets and in homes for ringing door-bells. Some may have noticed the larger installations for railway and other uses. Draw attention to the rotary transformer for changing the voltage-current relations of direct current. Mention remarkable high efficiency of transformers.
22. E. M. F. induced by make and break of an electric circuit. Choke coils and induction coils. *Application of the principle of induced e. m. f. by make and break coils to gas engine ignition.* *Understanding of ignition system of automobile.* *Understanding of the principle of Induction.*	Recall that an induced e. m. f. was the result of relative motion of a conductor and a field. Show that this was really a change in magnetic field relations and that in the transformer this is accomplished by the rise and fall of current values in the primary due to alternating current. In the jump-spark coil these changes are created mechanically by the interrupter. Couple this with the number of-turns-voltage ratio and so account for the very high voltage which makes the spark. Discuss self-induction and using laws already learned, show how a choke coil holds back the current as though it were resistance.
23. Electroplating and refining of metals. *Great commercial value of principle of electrodeposition.* *Faraday's Principle of Electrolytes.*	Deposit copper on carbon rod from copper sulphate solution and then remove the deposit by reversing the current. Discuss ionization and electrolytes. Plate the depression in a piece of paraffine caused by a warmed medal or ornament (coins suggest counterfeiting, hence omit) by coating it with black lead. From this develop principle of electrotyping. The subject of recovery of metals from ores in remarkably pure state naturally follows. Other commercial electrolytic processes as production of chlorine and metallic sodium should be studied.

Unit VII.

Radio

TIME:—APPROXIMATELY 1 WEEK

Specific Objectives and Desirable Outcomes	Content and Suggested Activities
A knowledge of a simple vacuum tube receiving set. *A knowledge of the proper method of installing a radio receiving set.*	Examine radio tube connections and diagram the tube to account for all the terminals. Connect filament to resistance and "A" battery and connect "B" battery to plate through millivoltmeter. Discuss carefully the direction of current flow in the plate circuit and point out contradiction of principle of electron flow and established plus and minus markings on the apparatus. Connect grid to secondary of coupler and connect to aerial with primary of coupler. Put condenser in ground connection. Complete necessary connections to "A" wires. Discuss carefully the region about a heated filament and show how rectification occurs there. Discuss the third electrode or grid and what it accomplishes. Show how a vacuum tube can be used for amplification. Remove milli-voltmeter and substitute phones. Enlarge set by adding one stage of amplification by use of transformer and tube. To learn effect of unidirectional conductivity of crystal upon wave diagram of alternating current, making audible modulated, high frequency, alternating impulses received upon the antenna.
Radium *To learn about the properties and uses of radium.*	Discuss Becquerel's experiment (1896) and work of Madame Curie.
Source	Pitchblende—note extreme scarcity of radium.
Effects	Affects photographic plate through substance—discharges electroscope — decomposes water — physiological effects. Dangers from handling.
Radioactivity	Radioactive effects apparently due to explosions of radioactive atoms. Distinguish alpha, beta, and gamma rays by difference in penetrating power. Note nature of alpha as positive ions of helium and of gamma rays as being X-rays.
Energy in radioactivity	Discuss spinthariscope, and the topic of radioactive decay resulting in lead.
Uses of radium	Zinc sulphide and radium salt for luminous numbers. Treatment of cancer. Note that the form used is usually chloride, bromide, or carbonate.
To understand cathode rays *Knowledge of the nature of cathode rays.*	Discuss: (if possible, demonstrate) electric discharges through gases and partial vacua. If apparatus is available, demonstrate (otherwise read) the cathode rays—heating effect, streaming electrons affected by a magnetic field. Study recent developments of cathode-ray tubes (Coolidge tube).

SPECIFIC OBJECTIVES AND DESIRABLE OUTCOMES	CONTENT AND SUGGESTED ACTIVITIES
To understand X-Rays *Knowledge of X-rays and their importance.*	Read about the discovery of X-rays, Roentgen. If possible, demonstrate the operation of an X-ray tube. View the hand and opaque objects by means of a fluoroscopic screen. Look up the work of Moseley. Investigate the uses of X-ray tubes.

REFERENCES

Text and reference books for students:

Black and Davis	New Practical Physics	Macmillan
Dull, C. E.	Modern Physics	Holt
Fuller, Brownlee, Baker	Elementary Principles of Physics	Allyn-Bacon
Gibson, C. R.	Electricity of Today	Seely Service
Jackson and Black	Elementary Electricity and Magnetism	Macmillan
Swope	Lessons in Practical Electricity	Van Nostrand
Thompson, Silvanus	Elementary Lessons in Electricity and Magnetism	Macmillan

Reference books for teachers:

Bliss, Howard H.	Elements of Applied Electricity	Holt
Croft, Terrell	Practical Electricity	McGraw
Jones, Harry C.	Electrical Nature of Matter	Van Nostrand
	Publications of the Bureau of Standards	
Timbie, W. H.	Elementary Electricity	Wiley
Woodring, Oakes, Brown	Enriched Teaching of Science in the High School, p. 119-146	Columbia Univ. Press (Teachers College)
Moyer and Wostrel	Practical Radio	McGraw

Text Books in Physics for students:

Harrow, B.	From Newton to Einstein	Van Nostrand
Hart, I. B.	Introduction to Physical Science	Oxford
Hart, I. B.	Makers of Science	Oxford
Heyl, P. R.	Common Sense of Theory of Relativity	Williams
Lunt, Joseph	Everyday Electricity	Macmillan
Millikan and Gale	Elements of Physics	

Reference for teachers and students:

Bragg, Sir William	Concerning the Nature of Things	Harper
Cajori, Florian	History of Physics	Macmillan
Comstock and Troland	Nature of Matter and Electricity	Van Nostrand
Darrow, F. L.	New World of Physical Discovery	Bobbs-Merrill
Kaempffert, W.	Popular History of American Invention	Scribners
Millikan, R. A.	The Electron	
Mills, John	Within the Atom	Van Nostrand
Thompson, A. J.	Outlines of Science (5v)	Putnam
Williams, H. S.	Story of Modern Science	Funk & Wagnalls

College Text—Kimball, Crewe, Weed and Palmer, etc. Watson, rev. Ganot, rev.

SAMPLE LESSON

Problem

To learn the law of reflection.

Preliminary Experiment and Questions

Problem

Where does a reflected image appear to be?

Directions

Lay a mirror on a table. Place an ink bottle, an open book, and other objects upon it. What is the appearance of the images? How far behind the mirror does the top of the ink bottle seem to be? The top of the book?

Write your name on paper while looking in the mirror. What do you observe?

Summary

State two rules as to the appearance of a reflected image.

Formal Experiment

Problem

Law of reflection.

Directions

Place the back edge of a mirror upon a line drawn parallel and about 5 cm. from the top of the paper. Stand a pin as an object in front of the mirror and near one side, several centimeters away from the mirror. Stand a second pin several centimeters in front of the mirror, but near the opposite side. Find a position where the image of No. 1 cannot be seen because of its reflected ray being cut off by No. 2. Place a third pin so that it will entirely hide No. 2 and the image of No. 1 in the mirror.

Connect pin points No. 2 and No. 3 with a line which will cross the reflecting surface. Connect point No. 1 and the points of incidence with a line. Erect a normal to the point of incidence and with a protractor measure to angle of incidence and the angle of reflection. Label fully.

Summary

How are the angles of incidence and reflection related as to size?

Define the term reflection.

State the law of reflection.

Development

From your observation mention five good reflecting and five poor reflecting surfaces. Analyze the reason for the difference in absorptive and reflecting power.

What relation exists between the reflective powers of a material and its color?

What do you understand by diffusion reflection? Arrange a simple experiment to illustrate your answer.

Report upon the per cent of diffuse reflection of different materials.

Explain how the optical illusion called Pepper's Ghost is produced—Demonstrate by use of the experiment.

Why is it difficult to look into a room from the outside through a window when the sun is shining brightly?

Many one-story factories receive their light from skylights which face north. Explain the reasons for such construction.

SAMPLE LESSON

Problem

The relation between the direction of motion and the direction of the lines of force and the direction of the e. m. f. induced.

Materials

A hollow cylindrical coil (500 turns No. 30), bar magnet, galvanometer (center zero), strong horseshoe magnet having small gap.

Procedure A

1. Test the galvanometer with a dry cell and sufficient protective resistance to show the direction in which the needle moves relative to the terminal by which the current enters the galvanometer.
2. Mark the coil or helix with chalk the direction in which the wire is wound upon it.
3. Connect the coil to the galvanometer.

Observation

Record the needle movement.

Thrust the N pole into the helix with each movement of the bar magnet up or down within the coil.

Conclusion

What does this experiment tell us concerning "the right hand rule," and the Law of Lenz?

Procedure B

1. Move a wire, the ends of which are connected to the galvanometer, downward between the poles of the horseshoe magnet.

2. Raise the wire through the same field.

Observation

Note the direction of the induced current produced each time the wire is raised or lowered.

Conclusion

What does this experiment tell us concerning Fleming's rule?

Development

What happens when a loop of wire in a generator rotates in the magnetic field, one part of the wire moving down while the part on the opposite side moves upward?

The N face of this rotating coil is always opposing the N pole of the field. The S poles are doing likewise.

What effect does this have? Does the current keep its direction or change it at each half-turn? What is an alternating current? A direct current?

SAMPLE LESSON

Problem

To acquire a knowledge of relative humidity and its importance.

Preliminary Discussion

1. Compare the body sensations in August and January.
2. What effect does "indoor climate" have upon the air passages and mucous membrane?
3. Why is hot tea a refreshing drink to the Egyptians in summer?
4. Explain what you mean when you say—
   "I think it will rain today."
   "I think it will be a fine day today."
5. Suggest causes for the nervousness of "fidgets" one experiences in an over-crowded auditorium.

Materials

Thermometers, calorimeter, hygrometers, ice.

Procedure

Distribute copies of "Tycos" and "Tycos Catalogs" published by Taylor Instrument Companies to accompany laboratory directions. Secure exhibit of Taylor Instrument Companies demonstrating how a hygrometer is made, also daily weather reports from newspapers and weather reports of Weather Bureau.

Directions and Observations

1. Place water to the depth of about an inch in a calorimeter.
2. In it, stand a thermometer.
3. To the water in the calorimeter slowly add a little ice, stirring thoroughly after each addition. Continue until a thin film of moisture appears on the outside of the calorimeter.
4. Look up the definition of the "dew point." (A thick deposit of moisture indicates that you have cooled the water too rapidly and passed beyond the dew point. In such a case repeat the experiment. If the air is dry or quite cool, it may be necessary to add a little salt in order to reach the dew point.)
5. Record the temperature at which the moisture appears.
6. Keep stirring and note the temperature at which the moisture disappears.

Experiments show that a cubic meter of saturated air contains at different temperatures the following amounts of water vapor:

2 grams at 10° C.	17 grams at 20° C.
5 " " 0° C.	30 " " 30° C.
9 " " 10° C.	597 " " 100° C.

7. After the dew point has been determined from the preceding experiment, note the temperature of the room.
8. Look up the definition of relative humidity.
9. Using some table like the one given above, note the number of grams of water vapor present in one cubic meter of saturated air at the temperature of the dew point you have just found, and record it.
10. Note the number of grams of water vapor present in one cubic meter of saturated air at the temperature of the room and record it.

11. Divide the quantity of water vapor present in the air by the amount that would be present if the air were saturated and express the result as per cent.

Record of Data

Dew Point

$$\text{Aver D} = \frac{T + t}{2}$$

Relative Humidity

$$H = \frac{w}{W}$$

T	t	Aver D	R	w	W	H

T = temperature when moisture first forms
t = temperature when moisture disappears
Aver D = average dew point
R = temperature of room
w = weight of water vapor contained in 1 cu. M. of saturated air at temperature of dew point
W = weight of water vapor contained in 1 cu. M. of saturated air at temperature of room
H = relative humidity expressed in per cent

Conclusion

Explain fully the relation between relative humidity and temperature.
Suppose the dew point is below 32° F. In what form will the vapor be deposited?

Development

Supplementary Home Topics
Prepare a simplified Comfort Chart for home use.
Compare the psychrometer and hygrodeik with the hygrometer used in the laboratory.
Arrange argumentative points in favor of proper humidity in the home.
How can we accomplish humidification with a radiant heating system?

Course of Study in Chemistry*

Introduction

The purpose of this course of study is to place before the teachers of Pennsylvania principles and facts most commonly included in a first course in chemistry, experiments to aid pupils to understand principles and to obtain facts, and several types of tests to suggest ways of testing pupils. Facts and phases of Chemistry not included may be added according to the needs of the various communities. Principles not included in the present course of study may be added in classes which are college preparatory. Increased emphasis may be placed on household or industrial chemistry in communities where a majority of the pupils will not study chemistry beyond a first course. The course of study is not intended to curtail teacher initiative or to standardize the chemistry course offered in the high schools of the State. It is designed to provide a working basis which will enable each boy and girl to come in contact with the basic principles and facts of chemistry. The initiative of the teacher in adjusting the course to the interests and aptitudes of the pupils in a particular community is vital and the committee does not wish to stifle it in any way.

A list of experiments, demonstration and laboratory, is offered to assist pupils, (1) to gain a clearer understanding of the principles involved, (2) to gain experience in handling apparatus, (3) and to continue to develop an orderly method of gathering data and forming conclusions. It will be necessary in most schools to supplement this list in accordance with the emphasis placed on phases of chemistry not included in the course of study. The list is purposely made up of the most elementary experiments to enable the pupil to connect the work with his experience. Teachers are urged to analyze their equipment needs and to requisition only material needed in the development of the course which they are teaching. Development of skill in handling apparatus may be accomplished through the use of commonly used and inexpensive apparatus. It is a product of carefully prepared instruction followed by adequate supervision on the part of the teacher. The development of a scientific attitude should be one of the outcomes of the chemistry course. The initiative, skill, attitude, and personality of the teacher has much to do with the way pupils learn and react.

Specimen objective tests are included in connection with the unit on water (Appendix), and are intended, primarily, to serve as illustrative material. It is necessary for the teacher to work out a balanced test program including pre-tests, teaching tests, summarization tests, tests on recognition of laboratory apparatus and technique, and finally general tests designed to test the efficiency of teaching and learning. The type of test used at any one time depends upon the nature of the materials. Some materials lend themselves to one type of test and others to another type. A complete battery of tests constructed for state-wide use would not be equally satisfactory in all districts, and would tend to prevent adaption of materials to community needs. The material included in this course has been arrived at from a number of sources, the most important of which are: (1) an analysis of ten or twelve textbooks of chemistry, (2) an analysis of regents board, college entrance board, and state examinations, (3) by reviewing the current writings on the teaching of chemistry (4) through the suggestions presented by approximately three hundred teachers of chemistry who analyzed the preliminary mimeographed course. The materials obtained were arranged in parallel columns. In developing its work the committee assembled in one list facts and principles common to all sources. Another list of facts and principles common to several other sources was assembled. Related experiments were then set up for each list of facts and principles. In addition, a number of books were reviewed and listed under the head of special subject references. These references may be used for enriching the course and for providing information on topics of special interest. The amount of material included in the two lists mentioned above exceeded the needs of a first course in chemistry. Careful study revealed that the materials in the second list were not suitable for all communities and could be eliminated. It was made up of such things as history of chemistry, organic chemistry, refinement of metals, household chemistry, and industrial chemistry. These topics may be made a part of the chemistry course where they are suitable for the interests and aptitudes of the children, and in schools where the initiative of the teacher can make them of interest to the pupils. It is to be understood that during the process of elimination, some member of the committee dissented on the exclusion of practically every topic. The facts and principles com-

*In the preparation of this course the committee wishes to express appreciation to the science teachers of the State, many of whom evaluated the preliminary course, making valuable suggestions. It is impossible to mention who contributed. The committee, however, wishes to give special consideration to the following: Doctor Edward E. Wildman, Director of Science, Philadelphia, and the chemistry teachers of Philadelphia. The preliminary outline was evaluated by these teachers and the suggestions made brought together by Doctor Wildman. Many of the suggestions made by these teachers were included.

Doctor A. J. Courrier, Assistant Professor of Chemistry, The Pennsylvania State College, and the group of science teachers enrolled in his class, "Course in Methods in Chemistry," during the summer of 1930. Doctor Courrier made a careful analysis of the course and the group of students working under him, who were Chemistry teachers in the schools of the State, gave the committee a highly technical and also a practical analysis of the material of the course.

The members of the science section of the Pennsylvania State Education Association gave special consideration to the materials of the course. These materials were presented in a preliminary form at the meeting of the Section in 1929.

mon to all sources were organized into units, mimeographed and sent to teachers of chemistry for trial. At the end of the school year of 1931, criticisms were asked from each individual to whom the materials were submitted. These criticisms were studied by each member of the committee. The committee then met and reconsidered the materials in light of the criticisms offered. After complete revision, a final comparison of the course of study with courses of study from other states and independent organizations indicated that the basic facts and principles of chemistry are included.

The materials are organized into seven units and each unit is made up of a number of blocks. There is little difference between the list of units in which the materials are organized and those set up by textbook writers and other committees. The greatest difference lies in that an attempt was made to set the materials up in a coordinate plan, the units and blocks along the Y axis, and the learning threads[1] along the X axis. Learning threads are those things which are common to all units, although the relative importance of a learning thread may vary from unit to unit.

It is suggested that, in place of an introductory unit often given in chemistry, some time be given to teaching pupils how to study chemistry. The coordinate outline which is being offered accompanied by a general study guide may be placed before pupils and interpreted. Detailed study directions may be placed in the hands of each pupil when the first unit is introduced. A unit on water was placed first on the list because (1) it is within the experience of the pupils, (2) because pupils have studied it somewhat in general science, (3) because of its importance in chemistry, and (4) because it is an easy approach to the study of hydrogen and oxygen. Beginning with the study of water enables pupils to concentrate on study method and the handling of laboratory apparatus. The order of the remaining units is thought to be reasonable but this order may be changed to suit local conditions.

Guiding Principles

1. The high school chemistry course should be used as an instrument in developing well rounded civic and social character.

2. The course of study in high school chemistry should be made up of those materials in the field of chemistry which will be of maximal worth in preparing young men and young women for more complete living.

3. The approach of this subject should be primarily psychological on the high school level.

4. The high school chemistry course should
   a. Show the role played by Chemistry in the intelligence and service departments of industry, with particular emphasis upon the industrial and commercial phases of life activities.
   b. Instill an intelligent appreciation of the contribution of Chemistry to human health and progress.
   c. Acquaint the student with the possibilities of Chemistry as a vocation.
   d. Contribute to scientific thinking by demonstrating the importance of suspended judgment when seeking truth.
   e. Develop the scientific method of approach in solving problems.

5. When organizing a learning program in a high school chemistry class teachers must keep in mind the fact that pupils differ in interests, abilities and capacities. Work within a group must be varied to take into consideration these facts.

6. The high school laboratory should be regarded as a place for motivation of learning, development of the more common laboratory techniques and skills and confirmation of well selected and practical laws, principles and theories. It is not a place for original research.

7. Sensory aids offer a rich field which should be utilized to the greatest possible extent by the chemistry teacher.

8. If the course is to be of optimal value in developing an appreciation of its daily and practical application to the problems of life the teacher must be a leader and a guide. To this end he should overlook no opportunity to acquaint himself with past and present discoveries and trends.

9. The idea of safety should at all times be kept in the minds of teacher and pupils. This applies to the selection of experiments, materials, laboratory techniques, and supervisory techniques.

The Laboratory Note Book

No discussion of laboratory procedure would be complete without a consideration of the pupil's note book.

It would seem wise, first of all, to ask ourselves what is to be the function of the note book in our course. Most teachers will agree that a well kept series of notes should be an aid to the pupil in the following ways:

(1) It should develop within him the technique of carefully checking and recording all results.

(2) It should supply a brief, accurate and honest record of the procedure, results and conclusions of each exercise that will give the instructor a true index of the pupil's progress.

(3) It should provide a collection of data which will at any time assist the pupil in reviewing or checking his laboratory work.

In order to fulfill these functions it is clear that the note book must fit the needs of the pupil in his laboratory work. Notes should not be so copious as

[1] Morneweck, Carl D.—Preparation and Partial Standardization of an Enriched Chemistry Testing Program and Some of Its Outcomes—Unpublished Doctor's Dissertation, University of Pittsburgh, 1930.
Gould, George—Experiment in the Supervision of American History, Graduate Studies in Education Volume 2, University of Pittsburgh, 1929.

to require an undue portion of the pupil's laboratory time or to require to spend outside time in writing them up. Unnecessary repetition should be avoided. Notes, then, should consist of a brief description of the procedure, written in the first person and past tense, a careful listing of results and a clear formulation of the conclusions. Such notes should then be quickly and accurately checked and corrected by the instructor and returned to the pupil for his own guidance. Sketches should be sectional rather than perspective and should merely serve the purpose of depicting the apparatus setups and relationships.

The following list of apparatus is taken from Bulletin, 1927, No. 22, Laboratory Layouts for the High School Sciences by A. C. Monahan, United States Office of Education, Washington, D. C.

LABORATORY EQUIPMENT FOR FIRST-YEAR CHEMISTRY

List A—Desk Apparatus (for 24 Students)

24 alcohol lamps, 4 oz. (or Bunsen burners).
24 blowpipes, brass, 8 inches.
12 reagent bottles, No. 108, for ammonium hydroxide.
12 reagent bottles, No. 106, for hydrochloric acid.
12 reagent bottles, No. 104, for nitric acid.
12 reagent botles, No. 111, for sodium hydroxide.
12 reagent bottles, No. 102, for sulphuric acid.
24 burette clamps.
24 crucible tongs.
24 cylinders, plain, 2 by 12 inches.
24 deflagration spoons, iron.
24 files, round, 4 inches.
24 files, triangular, 5 inches.
24 gauze squares, iron, asbestos centers, 5 inches.
24 mortars, with pestles, porcelain, 80 mm.
24 pneumatic troughs, galvanized armco iron.
24 ringstands, 2-ring.
24 sand baths, shallow, 4 inches.
24 test-tube racks.
24 tripods.

List B—Individual Apparatus (for 24 Students)

24 asbestos sheets, 5 by 5 inches.
24 beakers, 100 cc.
24 beakers, 250 cc.
24 beakers, 400 cc.
24 crucibles, porcelain, No. 0.
24 dishes, evaporating, porcelain, 75 mm. No. 00A.
24 flasks, 250 cc.
24 flasks, Erlenmeyer, 125 cc.
24 funnels, 75 mm.
24 gasometers, 50 cc.
72 glass plates, 10 by 10 cm.
24 graduates, cylindrical, 25 cc.
24 pipestem triangles, 2 inches.
24 pinchcocks, screw compressor.
24 rubber stoppers, 1 hole No. 1.
24 rubber stoppers, 1 hole No. 5.
24 rubber stoppers, 1 hole No. 4.
48 bottles, wide-mouthed, 2 oz.
72 bottles, wide-mouthed, 8 oz.
24 burettes, 50 cc.
24 cobalt glass plates, 50 mm. by 50 mm.
24 rubber stoppers, 1 hole No. 8.
24 rubber stoppers, 2 hole No. 4.
24 rubber stoppers, 2 hole No. 8.
24 rulers, Eng. and met., 12 inches.
24 spatulas, horn, 150 mm.
24 test tubes, ignition, 6 by ¼ inch.
24 test tube brushes.
24 test tube racks.
24 thermometers—10° to 110° C.
8 thistle tubes.
424 watch glasses, 3 inches.

List C—Apparatus and Stock for General Use

24 aprons, rubber.
3 balances, trip scales, agate bearings.
3 sets weights, iron, on holder, 10-500 g.
6 hand balances, improved.
6 sets weights, in blocks, 1 ctg.-20 g.
48 bottles, wide-mouth, glass stoppers, 4 oz.
12 calcium chloride tubes, 6 inches.
12 combustion tubes, 45 by 1.9 cm.
12 combustion boats, porcelain, 60 by 10 by 10 mm.
12 condensers, Leibig, 15-inch.
12 condenser clamps.
12 condenser-clamp holders.
3 sq. ft. copper sheet, No. 30.
3 spls. copper wire, bare, No. 28, 4 oz.
3 pkgs. corks, asstd. 0-11 (144).
3 cork borers (6 in set).
12 pkgs. filter paper, 11 cm.
3 pkgs. filter paper, 20 cm.
3 funnels, 125 mm.
12 funnels, separatory, with stopcock, 60 cc.
3 lbs. glass rods, 4-5 mm., asstd.
5 lbs. glass tubing, 5-7 mm., asstd.
3 hydrometers, universal.
3 hydrometer jars, 2 by 15 inches.
3 spls. iron wire, No. 28.
12 vials litmus paper, blue.
12 vials litmus paper, red.
8 magnifiers, tripod.
12 platinum loops, in glass handles.
1 roll picture wire, No. 1 (25 yds.).
8 retorts, glass-stopper, 125 cc.
60 ft. rubber tubing, 3/16 inches.
30 ft. rubber tubing, ¼ inch.
288 test tubes, soft, 4 by ½ inch.
144 test tubes, soft, 6 by ¾ inch.
8 water baths, copper, 5 inches.

List D—Chemicals

2 lbs. acid, acetic, glacial, C. P.
12 lbs. acid, hydrochloric, C. P.
14 lbs. acid, nitric, C. P.
1 lb. acid, oxalic, crystals, com'l.
1 lb. acid, phosphoric, ortho, 85 per cent C. P.
18 lbs. acid, sulphuric, C. P.
1 gal. alcohol, ethyl, denatured.
5 lbs. alum potassic.
1 lb. aluminum, metal turnings.
1 lb. aluminum, metal powder.
4 oz. arsenic, metal, cryst.
1 lb. arsenic trioxide, powder.
1 lb. ammonium nitrate, pure.
5 lbs. ammonium sulphate, com'l.
1 lb. ammonium sulphide, light.
2 lbs. ammonium carbonate, lumps, U. S. P.
2 lbs. ammonium chloride, pure, gran.
12 lbs. ammonium hydroxide, com'l.
1 lb. antimony, metal, lump.
1 lb. barium chloride, C. P.
1 lb. barium nitrate, powd. com'l.
1 lb. barium sulphate, C. P.
4 oz. bismuth, metal.
4 oz. bismuth chloride, C. P.
1 oz. bismuth nitrate, C. P.
5 lbs. borax, cryst., pure.
2 cans bleaching powder (12 oz. can).
4 oz. cadmium sulphate, C. P., cryst.
2 lbs. carbon bisulphide, pure.
2 lbs. calcium chloride, anhyd. lumps.
2 lbs. calcium chloride, dry granular.
2 lbs. calcium fluoride (fluospar) powd.
5 lbs. charcoal, wood, lump.
2 lbs. charcoal, animal, powd.
1 lb. chloroform, U. S. P.
4 oz. chromic chloride, C. P., green cryst.
4 oz. cobalt chloride, C. P.
1 oz. cobalt nitrate, C. P.
1 lb. copper chloride, C. P.
2 lbs. copper, metal foil, No. 36.
2 lbs. copper, metal, turnings.
5 lbs. copper sulphate, cryst., com'l.
4 oz. copper oxide, powd. black, C. P.
4 oz. copper oxide, wire, C. P.
2 oz. eosin.
1 lb. ether, U. S. P.
2 lbs. ferric chloride, U. S. P.
5 lbs. ferrous sulphate, cryst.
5 lbs. ferrous sulphide, gran.
1 lb. glycerine, C. P.
5 lbs. gypsum, lump.
2 lbs. hydrogen peroxide, 3 per cent U. S. P. hydrogen sulphide (make in laboratory).
2 oz. iodine, resub. cryst.
5 lbs. iron filings, clean.
5 lbs. iron powder.
2 sq. ft. lead, metal, sheet, 1/64 inch.
2 lbs. lead acetate, cryst., com'l.
2 lbs. lead nitrate, cryst., com'l.
5 lbs. lime (quicklime), in tin can.
2 lbs. litharge, lead oxide, mono., yellow, pure.
4 oz. magnesium, ribbon.
2 lbs. magnesium, sulphate, C. P.
5 lbs. manganese dioxide, gran.
5 lbs. marble chips.
8 oz. mercury, metal.
4 oz. mercuric chloride, U. S. P.
4 oz. mercurous nitrate, C. P.
4 oz. mercuric nitrate, C. P.
8 oz. mercuric oxide, red, U. S. P.
4 oz. nickel nitrate (ous), C. P.
2 lbs. paraffin, medium.
4 oz. phenophthalein, U. S. P.
8 oz. phosphorus, red.
1 lb. phosphorus, yellow, sticks.
5 lbs. plaster of Paris.
1 lb. potassium bitartrate, U. S. P.
1 lb. potassium bromide, U. S. P.
5 lbs. potassium chlorate, cryst., pure.
2 lbs. potassium chromate, cryst.
2 lbs. potassium chloride, pure.
1 lb. potassium cyanide, pure.
1 lb. potassium dichromate, cryst.
1 lb. potassium ferrocyanide, cryst.
2 lbs. potassium hydroxide, tech., gran.
4 oz. potassium iodide, U. S. P.
2 lbs. potassium nitrate, pure, gran.
4 oz. potassium perchlorate, cryst., U. S. P.
2 lbs. potassium sulphate, C. P.
1 lb. rosin.
1 oz. silver, foil.
2 oz. silver nitrate, pure, cryst.
2 lbs. soda, common baking (sodium bicarbonate).
4 oz. sodium, metal.
2 lbs. sodium acetate, cryst., com'l.
5 lbs. sodium chloride, fine, pure.
2 lbs. sodium carbonate, cryst., com'l.
2 lbs. sodium hydroxide, sticks, U. S. P.
5 lbs. sodium nitrate, pure.
1 lb. sodium peroxide, C. P.
2 lbs. sodium sulphate, cryst.
8 oz. stannic chloride, C. P., cryst.
1 lb. stannous chloride, pure.
1 lb. strontium nitrate, pure.
2 lbs. sugar, cane (procure locally).
2 lbs. sugar, glucose (dextrose) lump
5 lbs. sulphur, roll.
1 lb. tartaric acid, U. S. P., cryst.
1 lb. tartar emetic, pure.
1 lb. tin, metal, mossy.
2 lbs. zinc, metal, mossy.
2 lbs. zinc sulphate, pure, cryst.
2 lbs. zinc powder
2 lbs. zinc strips

List E—Reserve Stock

24 beakers, 100 cc.	12 cobalt glass plates, 50 by 50 mm.	24 flasks, Erleneeyer, 125 cc.
24 beakers, 250 cc.	24 crucibles, porcelain, No. 0.	6 funnels, 75 mm.
24 beakers, 400 cc.	3 cylinders, glass, 2 by 12 in.	3 graduates, cylindrical, 25 cc.
36 bottles, glass stopper, 4 oz.	24 dishes, evaporating, 75 mm.	6 doz. test tubes, hard, 6 by ¾.
12 burettes, 50 cc.	24 flasks, 250 cc.	24 flasks, Erlenmeyer, 125 cc.

Summary

Desk apparatus for 24 students	$150.00
Individual apparatus for 24 students	200.00
General apparatus	200.00
Chemicals	100.00
Reserve stock	75.00
Approximate total cost	675.00
Annual replacement	150.00

Some modifications have been made to the list as it appears in the original monograph but the material is essentially the same. It is not a required list of equipment but rather a guide to teachers in selecting those pieces of apparatus which will be of most service in developing the science program.

Prices given in the summary have been modified in accordance with the changes in the prices listed and also in accordance with the changes made in the original list.

An additional list of general equipment which should be provided for Chemistry follows: Balances; stills for distilled water; drying oven and water bath; gas generator.

The Coordinate Unit Organization of Chemistry

It has been the custom for about ten years to organize teaching materials into units. The purpose of gathering together related materials in this fashion has been to make sure that new subject matter presented may be closely related to past experiences. Materials arranged in this way have been taught by the recitation method and by individualized techniques, such as the Winnetka Plan, the Dalton Laboratory Plan, and the Mastery Technique. This treatment of a unit, presenting it first as a whole and then in its parts, has many advantages for both teacher and pupil.

There is one outstanding weakness of the unit plan as generally practiced which this course attempts to correct. While the materials of a subject are organized into interesting units, too frequently the learner, upon completing a course sees only a series of isolated concepts and unrelated bodies of information. It is necessary that the pupils understand at the beginning of a course that there are units of subject matter to be studied, but it is also imperative that they see the factors or phases which are common to all units, and the relation which each bears to the subject as a whole. It is of prime importance that students appreciate not only the inter-relatedness of units through the common elements, but that they see also the relative importance of the factors within each unit. This is necessary in order that the subject under consideration may become an integrated whole rather than a series of unconnected parts.

A plan of units cross-linked by means of common factors or learning threads is presented in this course of study. Neither the units nor the learning threads represent new subject matter. They are merely an arrangement of existing materials to enable the pupil to study chemistry more efficiently and intelligently.

It is suggested that the coordinate organization sheets and a detailed study guide be placed in the pupils' hands on the first day of school and that several days be spent explaining the organization of the course and how to use the guide. In addition to this general orientation, special directions should be provided for the study of each unit. If it is found that this program teaches pupils how to study chemistry, less instruction on how to study will be necessary for each succeeding unit.

On the organization sheets a triple "X" has been used for indicating factors which are considered highly important in each unit; a double "X" for important factors; and a single "X" for the relatively unimportant factors. While it is highly improbable that the units and common factors or learning threads proposed by the committee will be accepted by all teachers of chemistry, it is felt that they do form a practical foundation upon which the course may be based. The merits of the plan may be briefly outlined as follows:

1. The work for the entire year is placed before the teacher and pupil in concise form.
2. It reveals how important phases may be stressed systematically.
3. It presents an overview of the work.
4. It permits the addition of the industrial and commercial applications which may be desirable in particular communities.
5. It meets the need of reducing the amount of materials covered in a first course of chemistry.
6. It is intended to assist in the formation of study habits.
7. It is check against over-emphasis in fields of special interest on the part of the teacher.
8. It permits close supervision on the part of the principal and superintendent.

In order to illustrate how subject matter may be organized, certain phases of the first unit in the course of study are shown in detail. In planning the unit the following divisions are considered: I. pre-test, II. presentation lesson, III. a test following the presentation lesson, IV. guide sheets, V. test, and VI. bibliography.

I. The pre-test is used to inventory the background of knowledge of the pupils in order to discover which facts and principles are already known or understood.

II. The presentation lesson is intended to outline to the pupil, by means of discussion and demonstration, what is to be studied and to arouse his interest and curiosity for the purpose of stimulat-

ing his effort. The presentation for this unit follows:

Water is widely distributed over the surface of the earth. That "the earth is one-fourth land and three-fourths water," is a familiar statement. Our foods are largely water. Our bodily tissues are bathed in water. The weight of the body is largely due to water. It is so common that we fail to realize what a remarkable substance it is. Where did it all come from? Geologists have concluded that it is largely, if not altogether, volcanic in origin. (*) To show you this, I have before me a hydrogen generator from which hydrogen gas is escaping. I shall light this gas cautiously and you will notice that water forms and condenses as I insert the flame inside a test tube. When a volcano erupts, hydrogen gas or hydrogen sulfide gas is evolved. Great quantities of this gas uniting with oxygen under the influence of the lightning spark, causes water to form. Frequently, then, during volcanic disturbances we have tremendous rain storms.

Water is one of the most universal solvents known. We are familiar with solutions of sugar* or salt. Many gases dissolve in it to form all sorts of solutions. Water which has been exposed to air commonly contains air in solution. Fish could not live in water without this dissolved air. We think of it as dissolving almost anything. So to remove any matter, stain, or pollution from our hands, we turn to water and are almost in despair if it fails.

Some matter will dissolve in it in all proportions; as for example alcohol.* Others only to a very limited extent* as for example, lime, stone, or gypsum. But no substance can resist its solvent action under the influence of great heat and pressure. Even gold will dissolve in it if the pressure be made great enough. This accounts, according to scientists, for some of our ore veins as of silver, gold, platinum, etc.

Since nature has given us such a valuable, abundant and universal compound as water its solvent action and ability to hold in suspension impurities also presents many difficult problems. Suspended material and disease germs are removed by filtration or sedimentation. Sometimes with the addition of chemicals.* Mineral matter is removed by distillation.* To remove gaseous matter as for example dissolved oxygen so necessary to the animal life of the aquarium boiling is sometimes necessary.

With some substances it makes solutions like glue or mucilage. Such are called colloidal* solutions. Some solutions are like muddy water, not true solutions, partially settle out later and are called "suspensions."

Water has another very peculiar property in connection with its solvent action. While there are many other substances which make solutions, water forms practically the only solutions which permit the passage of an electric current.* For the moment we shall not delve deeply concerning this property. Its value to the chemist is beyond measure.

Water has other important properties of which we shall learn later.

Water is known as a stable substance. It takes the tremendous energy of an electric current or the equally tremendous energy of a white hot furnace to break it up. If we add a little sulfuric acid to this glass of water and pass a direct current through it, we notice two gases are formed.* One of these gases is combustible.* The other will cause even iron to burn in it, and yet water, the union of these two—the compound—is the substance used to put out fires.

So the substance, water, is really a union of two gases, and always in the proportion of two parts of one to one part of the other. These two gases, the combustible hydrogen, and oxygen, which causes things to burn in it, can be secured in other ways. If, for example, we heat a tube containing a mixture of potassium chlorate, a substance containing oxygen, with a pinch of another substance called manganese dioxide, oxygen is then formed.* Also, if we heat mercuric oxide, oxygen will be liberated. Wrapped up in this latter experiment are the beginnings of freedom, political and spiritual, as we shall learn later. A little hydrochloric acid added to the zinc in this test tube* will release the other gas which we found is a constituent of water.

Water has a unique property most valuable to man. It expands on freezing. As it solidifies it becomes less dense and floats on the surface. Were it not for this, the temperate regions of the world would be uninhabitable. The heavier unfrozen water sinks to the bottom of the lake. We can always know what the temperature of the bottom of the ocean is, knowing the temperature of water at its greatest density.

Its high latent heat of vaporization causes seaport cities to have a more even climate than that of the interior communities.* Notice the charts showing the isothermal lines.

It is no wonder, when we begin to conceive all these things, that we realize the tremendous importance of this most abundant of compounds.

III. This is followed by a test which will give some notion of the efficiency of the presentation.

IV. Following the presentation test the guide sheets are placed in the hands of the pupils to direct their efforts and thinking. The Guide Sheet for this unit follows:

Guide Sheets

1. Ascertain where the water that covers the earth originated.
2. Enumerate as many substances as you can which in their natural state do not contain water.
3. What makes the water in the river yellowish in color? Is it the dissolved matter or suspended matter?

*4. Sometimes muddy water can be quickly cleared by add-

*Demonstration.

*Questions so marked should be proved experimentally either by the instructor as a demonstration, or as a laboratory experiment by the student.

ing some alum or alum and lime. Is this ever used for purifying water on a large scale?

5. We know that the water of the Great Salt Lake is very salty. Where did the salt come from? We often say because the lake has no outlet, hence is salty. In Maine there are many so-called land locked lakes yet the water is not salty. Can you explain? Is the fact of no outlet the only factor.

*6. Add a few drops of silver nitrate to your glass of drinking water.
Ask the instructor to explain the change in color of the water.

*7. Repeat this with a glass of distilled water from the laboratory.
Be sure the containers are clean.

*8. Evaporate a quantity of water from the tap upon a watch glass. Where does the residue come from? Repeat with distilled water.

*9. Sample the distilled water from your nearest filling station. You may be surprised at the results.

10. Pittsburgh filters all her drinking water. Will this remove dissolved mineral matter? What will it remove?

11. What becomes of the mineral residue after the water in the locomotive boiler has been converted into steam?

12. What effect does a continually added layer of mineral matter have on the efficiency of the locomotive boiler? Would this difficulty be greater in a marine boiler.

*13. When you remove the stopper from the ginger ale bottle bubbles of air (?) seem to be coming off. Sometimes it "fizzes." Is it air? Why didn't it "fizz" before you removed the stopper? What general effect has pressure on gases dissolved in water? Is the ginger ale, ale? Or is it mostly water?

*14. Distilled water is very clear. Would it be well to add that to your aquarium in which you wish to put gold fish?

15. Water that is to be used in steam boilers is sometimes run into tanks with scrap iron. This is to reduce its corrosive action. Why?

16. Suppose a piece of brightly polished steel were placed in a container of pure distilled water previously boiled. Why boiled? Would it rust provided air were excluded?

17. The plumber does not advocate the removal of water from the hot water heater in summer. Explain.

18. What makes water hard?

19. What does the laundress do to soften hard water?

20. Central Pennsylvania is a limestone region. It also has many limestone caves. What has water to do with this? What is the coating inside grandmother's tea kettle? Is it similar to a stalactite chemically?

*21. Rain water makes suds freely but hard water does not. Could soap be used to measure water hardness?

22. What is the principle of the slow sand filter, the rapid?

23. Clorine is added to the drinking water of cities. What purpose is there in this? If it kills bacteria, will it kill gold fish?

24. Burlington, Vermont ran the city sewers into Lake Champlain. They drew their water for drinking from the lake. The water intake was comparatively close to the shore. After an epidemic of typhoid fever the intake was removed a mile further out into the lake. The water now appears to be safe for drinking purposes. Will sedimentation purify water?

25. The chemist has many delicate analyses to make. From what kind of water does he prepare his solution?

26. What is the weight of one cubic centimeter of water at 4°C?

27. What is the temperature of the water at the bottom of a lake whose surface is frozen? At the bottom of the ocean? Why would it be the same?

28. At what temperature does water freeze under ordinary conditions?

29. Under what conditions does it boil at 100°C?

30. Could ice be colder than the freezing point of water?

31. Is the water in a locomotive boiler under greater pressure hotter than 100°C?

32. Could water in the locomotive boiler really boil?

33. What effect on the boiling temperature has the removal of pressure on water in a boiler?

The information necessary to answer the question or prove the statement may be obtained by experimentation or by study of textbook or reference materials. Study of questions or statements involving textbooks or reference materials may be done during the class period or at some other time. The most satisfactory procedure is to organize a divided study program with demonstration and individual laboratory work carefully correlated.

V. An objective test is administered covering the materials in each block. It may be followed by a summarization test after all the materials in the unit have been studied.

The bibliography is to be used by teacher and pupils. Certain references are for the benefit of the teachers. Others may be used by all members of the class.

BIBLIOGRAPHY ON UNIT I

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MUIR, M. M. PATTISON.—Heroes of Science, Chemists Society for Promoting Christian Knowledge, London, 1883. pp. 1-29.

*Questions so marked should be proved experimentally either by the instructor as a demonstration, or as a laboratory experiment by the student.

PIERSON AND SCHUCHERT.—Geology. Vol. I. p. 203. Ibid. Vol. II. p. 65.

SMITH, E. H.—"Some Early Chemical Symbols." Journal of Industrial and Engineering Chemistry. Vol. XVI (1924) p. 406.

WELLS, H. G.—Outline of History. Macmillan Co. Chap. I, II.

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A unit of subject matter including a pre-test, a presentation lesson, a test following the presentation lesson, guide sheets, tests, and bibliography with demonstration and individual laboratory experiments carefully correlated lends itself to a variety of treatments, and emphasizes the necessity of a directed learning program.

MAJOR UNITS	ELEMENTS	ATOMS	SYMBOLS	FORMULAS	MOLECULES	COMPOUND	MIXTURES	VALENCE	EQUATIONS	DEFINITE PROPORTIONS	CHEMICAL CALCULATIONS	IONIZATION	THERMAL CHANGES
I. WATER	XXX	XX	X	X	XXX	XXX	X	X	XX	XXX	X	X	XX
II. ACID BASES SALTS	X	XX	X	XX	X	XX	X	XX	XX	XXX	XX	XXX	XX
III. METALS CARBONS	XXX	X	X	X	XX	XXX	XXX	XXX	XX	XX	XX	XXX	XXX
IV. NON-METALS	XXX	X	X	XX	XX	XXX	X	XXX	XXX	XX	XX	XX	X
V. CARBON IN LIFE COMPOUNDS CARBONATES	XX	X	X	XXX	XXX	XXX	X	XXX	XX	X	XX	XXX	XXX
VI. SOLUTIONS IONIZATION AND MATTER	X	XXX	X	XXX	XXX	XXX	X	XXX	XXX	XX	X	XXX	X
VII. THE ELECTRON THEORY	X	X	X	XXX	XXX	XXX	X	XX	XXX	XXX	XXX	X	XXX

UNITS AND BLOCKS

UNIT I
Water

Block 1. Water as a Solvent
Block 2. Water as a Compound
Block 3. Oxygen
Block 4. Hydrogen

UNIT II
Acids—Bases—Salts

Block 1. A Study of Acids
Block 2. A Study of Bases
Block 3. A Study of Salts

UNIT III
Metals

Block 1. Family Relationships and Atomic Numbers
Block 2. Purification of Metals
Block 3. Metals that Touch our Everyday Life

UNIT IV
Non-Metals

Block 1. Air and the Atmosphere
Block 2. Sulfur and its Common Compounds
Block 3. The Halogen Elements and Fluorine
Block 4. Phosphorus and its Compounds

UNIT V
Carbon

Block 1. Carbon a Constituent of all Life Compounds—Foods
Block 2. Fuels
Block 3. Organic Acids, Base and Salts (Esters, Alcohols and Soaps)

UNIT VI
Solution and Ionization

Block 1. Solutions
Block 2. Ionization

UNIT VII
Matter—The Electron Theory

Unit I.

WATER

Water, the most common substance within our experience, is the most important. The subject may be introduced by a class discussion of the necessity of water to all life, animal and vegetable.

Block 1. Water the Universal Solvent

A. A study of natural waters.

1. Natural waters are never pure.
   a. The impurity depends upon the source and the course of the water.
   How does the sea get its salt?
   b. The result of evaporation.
   (1) The process of evaporation.
   (2) Residues obtained by evaporation of different samples of natural waters of the locality.
   c. Gases in solution in water.
   Why can goldfish not live in water that has been boiled?
2. Summarize the solvent powers of water.
3. Consider the effect of impurities in water upon:
   a. Health (organic impurities in suspension)
   b. Boilers, automobile cooling systems (dissolved minerals)
   c. Soap and textiles (mineral impurities)
   d. Dyes (mineral and organic impurities)

B. The purification of natural waters.

1. The method to be used depends upon two factors:
   a. What impurities must be removed?
   b. What is the cheapest method for removing them?
2. Purification for hygienic purposes.
   a. Filtration.
   (1) Slow sand filters.
   (2) Rapid filters
   (a) Treatment of water before filtering
   (3) Chemical treatment to destroy disease producing organisms.
   b. Boiling
   c. Distillation
3. Purification for industrial purposes
   a. Softening of boiler water, and water for the laundry
   (1) Essentially the removal of mineral water from solution in water.
4. The properties of completely purified water.
5. The use of water as the standard of mass.

C. Experimental Evidence

1. Evaporate sample of ground water.
2. Evaporate sample of milk, tomato, etc.
3. Purifying city water.
   a. Mineral substances.
   b. Organic impurities.
4. Dissolved oxygen—boiled water does not rust steel.
5. Fruits and vegetables contain H_2O as solvent for mineral salts.
6. Chemical content of H_2O influences plant growth.
7. Hard water (Perm. and Temp.)
8. Classes of solutions.
   a. Undersaturated.
   b. Saturated.
   c. Supersaturated.
9. Conditions effecting solution.
   a. Gases.
   b. Solids.
10. Non-soluble substances.

Block 2. Water as a Compound

A. The effects of energy applied to water.

1. Heat, a form of energy.
   Definition of energy.
2. Change of volume of water upon change of temperature.
   a. Definition of temperature.
   b. Temperature measurement and standards.
3. Energy in the form of electricity applied to water.
   a. Conditions necessary for conduction of electric current through water.
   b. The products of decomposition of water, oxygen and hydrogen.

B. Constant volume ratio of products.

1. The exact weight composition of water, method of determination. The work of Morley. (biographical)
2. Introduce definitions of: element, atom, symbol, compound, molecule, formula, atomic weight, molecular weight.
   a. The simple equation (based upon the decomposition of water).
   b. Simple calculations.
3. Investigate the relationship between water (moisture) and the rusting and corrosion of metals.

C. Water the best known compound.
  1. Found universally.
    a. In animal and vegetable tissue.
    b. In air.
    c. In earthy material, i.e., rocks, soil.
    d. In streams, lakes, rivers, oceans.
    e. In many crystals chemically combined as water of crystallization.

D. Experimental activities
  1. Hydrogen burning in a test tube open to air.
  2. Hydrogen burning in pure oxygen.
  3. A gas as artificial illuminating gas or methane burns producing water.
  4. Copper oxide heated in stream of hydrogen.
  5. Steam passing over heated, finely divided metals.
  6. Explode hydrogen and oxygen.
  7. Electrolysis of water.
  8. Water of crystallization.
  9. Deliquescent substances.
  10. Hygroscopic substances.

Block 3. Oxygen

A. Informational.
  1. Definitions and descriptions.
    a. Catalytic agent.
    b. Peroxide.
    c. Oxidation—slow, rapid.
    d. Reduction.
    e. Combustion.
      Kindling.
      Spontaneous vs. slow oxidation.
    f. Ozone.
    g. Nascent oxygen or hydrogen.
  2. Properties.
    a. Physical.
      (1) Color- odor- taste- solubility- natural state of matter.
    b. Chemical.
      (1) Not combustible.
      (2) Supports combustion.
      (3) Combines readily with most other elements.
      (4) Combines in more than one ratio with other elements.

B. Experimental and Demonstration.
  1. Preparation.
    a. Demonstrate that oxygen obtained from water supports combustion brilliantly. Compare burning in air with that in pure oxygen.
    b. Discuss the importance of oxygen in air, with especial reference to respiration and combustion.
      Discuss the importance of the use of oxygen in cutting and welding metals.
    c. Artificial respiration with oxygen. Oxygen helmets.
    d. Sources of oxygen other than water.
      (1) Decomposition of mercuric oxide.
        (a) The historical significance of this method.
        (b) Priestley (biographical).
        (c) Lavoisier and the beginning of chemical science (biographical).
        (d) This reaction expressed as an equation, in the language of chemistry.
      (2) Decomposition of potassium chlorate.
          Simple catalysis—catalytic agents. The use of the equation to express this reaction.
        Oxygen obtained from the air.
          Fractional distillation of liquid air.
      (3) It would be well to emphasize at this point that oxygen is in every case obtained from something that already contains it.
    e. Catalysis.
  2. Properties.
    a. Oxygen is not combustible.
    b. Oxygen is a good supporter of combustion.
  3. Reduction.
    a. Hydrogen over a heated oxide.
  4. Oxidation.
    a. The general subject of oxidation and oxides.
      Combustion; the production of heat by oxidation processes.
        Spontaneous combustion.
          Causes, examples and prevention.
    b. Rusts.

Block 4. Hydrogen—The Lightest Element

A. Properties.
  1. Physical.
    a. Hydrogen lighter than air (demonstration).
    b. Color, odor, taste, solubility.
  2. Chemical.
    a. Combustibility.
      (1) Pure.
      (2) When mixed with air.

B. Uses.
  1. Reduction of oxides (rare).
  2. As fuel (oxyhydrogen flame).
  3. Hydrogenation of fats and oils.
  4. Inflation of dirigibles.

C. Informational.
  1. Definitions and explanations.
    a. Compounds.
    b. Mixtures.

c. Elements.
d. Molecules.
e. Formulas.
f. Atoms.
g. Symbols.
h. Equations.

D. Displacement series.

E. Preparation — Commercial and laboratory methods.
1. Preparation from water by means of the electric current.
2. Preparation from water by displacement with metals.
a. Reaction of sodium and calcium with water.
b. Expression of this reaction by means of the equation.
c. Reaction of red hot iron with water.
d. Expression by means of the equation.
3. Sources of hydrogen other than water.
a. Production from acids by displacement with a metal.
b. Use of the equation to express this reaction.
4. Calculations of simple numerical problems based upon the various methods of obtaining hydrogen.

F. Commercial uses.

G. Experimental evidence.
1. Decomposition of water.
a. Action of electricity.
b. Action of an active metal.
(1) Calcium (individual).
(2) Sodium or potassium (demonstration).
(3) Displacement by a metal in steam (individual).
Zinc-iron-magnesium.
c. Displacement in an acid by a metal.
Iron or zinc and hydrochloric or sulfuric acid.
d. Demonstrate that hydrogen from water burns with great heat but without color. It may be shown that water is the product of this combustion.
e. Class discussion of the importance of this element as an essential constituent of living tissues, of water, as a common constituent of fuels, and as an inflater for balloons.

UNIT II.

Acids—Bases—Salts

Block 1. A Study of Acids

A. Informational.
  1. Acids, common examples.
  2. Characteristics of acids.
     The hydrogen ion, distinctive of acids.
  3. The usual simple tests for acids.
     a. Indicators.
     b. Effects upon metals.
     c. Effects upon bases.
     d. Taste.
  4. Types and classes of acids.
  5. Acid anhydrides.
  6. Acid radicals.
  7. Nomenclature of acids.
  8. Preparation of most common acids.

B. Experimental.
  1. Action of fruit juices on indicators.
  2. Action of laboratory acids on indicators.
  3. Acids in fruit and vegetable juices.
     Taste of acids.
  5. Testing of acidity of soils with litmus.
  6. Dry acids—no effect on indicators.
     a. Solid.
     b. Gaseous or liquid.
  7. Acid solutions with water but not alcohol or many other solvents.
  8. Acid with an oxide.
  9. Acid with a base.
     a. Action of non-volatile acids.
  10. Strong acids with salts.

C. Demonstration.
  1. Preparation of SO_3 (Contact process).
  2. Ionization about the poles of a D C current.
     a. Commercial current detector.
  3. Certain indicators detect strength of acidity of color.

Block 2. A Study of Bases

A. Informational.
  1. Bases, common examples.
  2. Characteristics of bases.
     a. The hydroxyl ion, distinctive of bases.
  3. Simple tests for bases.
     a. Effects upon common indicators.
     b. Effects upon metals such as magnesium and aluminum.
  4. Preparation of typical bases.

B. Experimental and demonstration.
  1. Properties and uses of common household bases.
     a. Household ammonia.
     b. Baking soda (Basic salts).
     c. Washing soda.
     d. Limewater.
  2. Properties and uses of common laboratory bases.

Block 3. Salts

A. Informational.
  1. Neutralization, common examples.
     a. The products of neutralization.
        (1) Water, always a product.
        (2) A salt, the by-product.
     b. Determination of the end point in neutralization.
  2. Salts, the by-product of neutralization.
     a. Characteristics of salts.
     b. Types of salts.
  3. Degree of ionization of solutions.
     a. Conductivity of solutions dependent upon degree of ionization of the solution.
     b. "Strength" of acids and bases dependent upon extent to which ionization has taken place.
  4. Mass action.
     a. Simple statement, with illustrative examples, of the
     b. Law of Mass Action.
     c. Equilibrium in solution.
     d. Precipitation and precipitates.
  5. Ionic equations.

B. Experimental.
  1. Preparation of a salt.
     a. Acid and base (NaOH and HCl)
     b. Metallic oxide and an acid (FeO and H_2SO_4)
     c. A salt and an acid (NaCl and H_2SO_4)
     d. A metal and an acid (Zn and H_2SO_4)
     e. A salt and a base ($FeCl_2$ and NaCl)
     f. A salt and a salt ($HgNO_3$ and NaCl)
     g. An acid anhydride and a base (CO_2 and $Ca(OH)_2$)
  2. Study of dissociation.
     Dissolve in water and test with litmus.
     a. When it contains H+ ($NaHCO_3$ — NaH SO_4 and $KHC_4H_4O_6$)
     b. When found by reaction of strong acid on weak base ($CuSO_4$)
     c. When it contains OH—
     d. When formed by reaction of weak acid on strong base ($Na_2C_4H_4O_6$)

e. When formed by reaction of a strong acid on strong base (NaCl)
f. When formed by reaction of weak acid on weak base ($Mg_3(C_6H_5O_7)_2$)

C. Demonstration.
1. Dissociation of salt solutions.
2. Law of mass action.

D. Discussion.
1. Dissociation.
2. Non-dissociated substances.
2. Solubility.
4. Volatility.
5. Ionization and conductivity.
6. Law of mass action.
7. Neutralization.
8. Hydrolysis (acid salts—basic salts—neutral salts).
9. Alkalies.
10. Naming salts.
   a. Per-ate salts
   b. ate salts
   c. ite salts
   d. hypo-ite salts
   e. ide salts
11. Reactions that run to completion.
   a. Formation of water as one product.
   b. Formation of volatile substance as one product.
   c. Formation of an insoluble substance as one product.
12. Some common salts.
   (names and uses)
13. Affect upon boiling point and freezing point.
   a. Electrolyte.
   b. Non-electrolyte.

Block 4

A. Solutions.
1. Common examples of solutions.
2. Distinguishing characteristics of solutions.
   a. Solutes and solvents.
   b. What constitutes a solution.
   c. The density of solutions.
   Specific gravity. Standards.
3. Conditions affecting the degree of solution of solids, liquids and gases in various solvents.
   Henry's Law.
4. Types of solutions.
   a. Diluted solutions.
   b. Saturated solutions.
   c. Supersaturated solutions.
5. Crystallization from solutions.
   a. Conditions under which crystallization may take place.
   b. Types and examples of crystals.
6. Suspensions.
   a. Temporary suspensions.
   b. Emulsions.
      (1) Conditions of formation.
      (2) Familiar examples.
      (3) The action of soap lather in washing.
   Colloidal suspensions.
      (1) Technical and industrial examples.
      (2) Colloidal suspensions in the living body.
      (3) The Browian movements and their explanation in the light of the kinetic molecular theory of matter.
7. Normal solutions.
   a. Definition.
   b. Calculation of normal solutions.
8. A study of hydrolysis, as exemplified by the reaction of solutions of the compounds of antimony and bismuth with water.

B. Ionization.
1. The conductivity for electricity of various solutions.
2. The effect of varying the amount of solute upon the boiling points of solutions.
3. Comparison of the boiling points of solutions in which there is equal molecular concentration of solute.
   a. In case the solution does not conduct electricity.
   b. In case the solution does conduct electricity.
4. Discuss the relationship between the boiling points of solutions and their conductivity for electricity.
5. The electrolysis of solutions.
6. The ion.
   Color of solutions.

C. Valence.
1. Discussion of the principles of valence, and the assignment of values to elements and radicals.
2. Relation between the extent of ionic charges and valence of ions.

UNIT III.

Block 1. Family Relationships and Atomic Numbers

A. Groups and families of elements.
   Classification upon the basis of resemblance or difference.

B. The investigations of Mendelejeff (Biographical).
   1. The periodic arrangement of the elements.
   2. Discussion of the general tendencies of elements in various positions in the arrangement.
   3. Statement of the periodic law.
   4. Discussion of defects in the arrangement.
   5. Uses which have been made of the table of elements, arranged according to Mendelejeff's classification.

C. Moseley's atomic numbers.
   1. Biographical background.
   2. Moseley's system compared with Mendelejeff's system.
      a. Its greater simplicity.
      b. Greater reliability.

D. Current opinions and contributions in this field at this time may be profitably read and discussed.

E. The displacement series.
   1. Experimental proof.
   2. Relation to valence and to formula writing.

F. General characteristics and behavior of metals.
   1. Position of the metals in the periodic arrangement of the elements.
   2. Relative chemical activities of the metals, as shown by the displacement series.

Block 2. Purification of Metals

The Metals

A. The economic importance of the metals through the ages.

B. What are the metals?
   Typical characteristics.

C. Sources of supply.
   Forms of occurrence.

D. General methods for preparing metals from their compounds.
   1. Separation of the native metal from dross.
   2. Reduction of the oxide.
      a. Commonly used reducing agents.
      b. The use of fluxes.
   3. Reduction of oxides obtained by roasting sulfides.
   4. Reduction of oxides obtained by decomposing carbonates.
   5. Electrolysis of a compound of the metal, usually a chloride or a hydroxide.

E. Chemical control in industry as exemplified in the metallurgical industries.
   1. Examples in specific industries, particularly local industries.
   2. Institutes of research.
      The Mellon Institute of Industrial Research.

Block 3. Metals That Touch Our Everyday Life

The metals to be considered as generally important are: iron, copper, lead, zinc, tin, calcium, sodium, aluminum, silver, and silicon.

A. Iron.
   1. Economic importance of this metal.
      Common uses.
   2. The mining and transportation of iron ore.
      Forms and composition of iron ore.
   3. The metallurgy of iron.
      a. The blast furnace.
         (1) Details of construction.
         (2) Details of operation.
             Chemical reactions involved.
         (3) Characteristics of product.
      b. The Bessemer converter.
         (1) Construction and operation.
             Chemical operations involved.
         (2) Characteristics of product.
      c. The open hearth furnace.
         (1) Construction and operation.
             Chemical reactions involved.
             The principle of the regenerative furnace.
         (2) Characteristics of product.
             The tempering of steel.
   4. Important alloys of steel.
      a. Use of chromium, vanadium, manganese and tungsten in making steel alloys.
      b. Characteristics and uses of steel alloys.
   5. Important compounds of iron.
      Compounds of different valences.

B. Copper.
   1. Economic importance and uses.
   2. Sources of the metal.
   3. Metallurgy, including refining by electrolysis.
      Electroplating of metals.
      Electrotyping.
   4. Properties of copper.
   5. Important compounds of copper.

C. Lead.
   1. Economic importance and common uses.
   2. Sources of the metal.
   3. Metallurgy.
   4. Properties.
   5. Important compounds.
      Paints.

D. Zinc.
   1. Economic importance and uses.
   2. Sources.

3. Metallurgy.
4. Properties.
5. Important compounds.
   Alloys in which zinc is a constituent.
6. Galvanizing.

E. Tin.
1. Importance and uses.
2. Sources and metallurgy.
3. Properties.
4. Important compounds.
   "Loading" of silks with compounds of tin.
5. Tin plating.
   The development of the canning industry.

F. Sodium.
1. Economic value of compounds of sodium.
2. The occurrence of sodium.
3. Extraction of the metal.
4. Properties.
5. Important compounds.
   a. The production and uses of common salt.
   b. Sodium carbonate.
      (1) Production by the Solvay process.
      (2) Characteristics in solution.
      (3) Uses.
   c. Sodium bicarbonate.
      (1) The reaction for preparation.
      (2) Uses.
   d. Sodium nitrate.
      Sources and uses.
   e. Sodium sulfate.
      Preparation and uses.
   f. Sodium hydroxide.
      (1) Different methods of preparation.
      (2) Properties.
      (3) Uses.
          The chemistry of soap making.
6. Treat briefly the important compounds of potassium at this point.

G. Calcium.
1. Calcium in building materials.
   a. Discuss the use of compounds of calcium as building materials.
   b. Hard water as an economic problem.
2. Compounds of calcium.
   a. Calcium carbonate.
      (1) Forms of occurrence.
      (2) Uses.
          Building material.
          Flux in metallurgy.
          Source of calcium oxide.
          Preparation of calcium oxide, "burning lime."
          The chemistry of mortar.
          "Liming" of soil.
      (3) Solubility in water containing dissolved carbon dioxide.
          Calcium bicarbonate.
            Temporary hardness in water.
            Formation of limestone caves.
   b. Calcium sulfate.
      (1) Occurrence as gypsum.
      (2) The manufacture of Plaster of Paris.
      (3) A study of the hardening of plaster when mixed with water.
      (4) Permanent hardness of water.
          The chemistry of water softening.
3. Mention important compounds of magnesium, barium and strontium.

H. Aluminum.
1. The place this metal holds in modern life.
2. Occurrence of the metal.
3. Metallurgy by the Hall process.
   The work of Hall (Biographical).
4. Properties.
   a. Behavior toward oxygen at high temperatures.
      The Thermit process.
5. Important compounds.
   a. Alums.
   b. Clays.

I. Silver.
1. Reasons for the extensive use of this metal in the home and in coinage.
2. Occurrence and metallurgy.
3. Properties.
4. More important compounds and their properties.
5. Silver electro-plating.

J. Silicon.
1. Discussion of the economic importance of compounds of this comparatively unknown element; pottery, brick, and other clay products; glass, cement, and carborundum.
2. Silicon dioxide.
   Occurrence.
     Sand and quartz.
3. Glass and its manufacture.
   a. The materials of glass manufacture.
   b. The glass plant and its construction and equipment.
   c. The chemistry of glass making.
   d. The chemical nature of glass.
4. Silicates.
   a. The acid character of silicon dioxide in the presence of basic oxides at high temperatures.
   b. The preparation of sodium silicate.
      Uses of sodium silicate, "water glass" as a preservative solution for eggs; as a cement.
   c. Magnesium silicates.
   d. Aluminum silicates, "clays."
      (1) The manufacture of pottery ware.
          Stoneware, porcelain and chinaware.
            Glazes and glazing.
      (2) Manufacture of brick.

(3) Hydraulic cement.
Relation of the cement industry to building industries.
The materials for the manufacture of cement.
The process of cement manufacture.
Types of compounds formed.
Compare the chemistry of the hardening of cement with that of the hardening of mortar.

5. The resemblance of silicon, chemically, to carbon, as indicated by its position in the periodic arrangement of the elements.

K. Radium.

1. The use of self-luminous materials.
   Application to watch and clock faces, etc.
2. Sources of radium.
3. The preparation of radium salts.
   The Curies (Biographical).
4. Some of the problems opened up by the investigation of the disintegration of the radium atom.
   The structure of the atom.
5. The use of radium in medicine and in surgery.

Unit IV.

Block 1. Air and Atmosphere

A. The atmosphere and its components.

Demonstrate that air is material; that it has weight.

1. A study of the composition and properties of air.
    a. Methods for the determination of the amount of oxygen in the air.
    b. Moisture in the air.
        (1) Demonstrate presence.
        (2) The determination of the amount of moisture in air.
        (3) Humidity of the air.
        (4) The problem of ventilation in buildings.
        Relation of proper ventilation to health.
        Importance of control of humidity.
    c. Nitrogen in the air.
        (1) Nitrogen a residue after the extraction of oxygen from air.
        Discuss active and inactive elements.
        The determination of the amount of nitrogen in air. (Note: If yellow phosphorus is used in this determination, only very small quantities should be placed in the care of students. Red phosphorus may be substituted with sufficiently accurate results, without danger.)
        (2) Importance of nitrogen to life forms.
        Absorption of nitrogen by certain plants.
        Nitrogen-fixing bacteria.
    d. Dust in the air.
        (1) Relation to formation of fogs.
        (2) Dust and disease.
    e. Carbon dioxide in the air.
        (1) Demonstration of the presence of carbon dioxide.
        (2) Determination of the amount of carbon dioxide in air.
        (3) The function of carbon dioxide in life processes.
        The carbon cycle.
2. The uniform composition of air.
3. Air is a mixture, not a compound.

B. Effects of the application of certain forms of energy to air.

1. Behavior of air under change of pressure.
    a. The measurement of the pressure of the air: the barometer.
    b. The principle and applications of Boyle's Law.
    c. Standard pressure for the measurement of the volume of gases.
2. The behavior of air under change of temperature.
    a. The principle and application of Charles' Law.
    b. Standard temperature for the measurement of the volume of gases.
    c. The absolute scale of temperature.
3. The kinetic molecular theory developed in explanation of the behavior of air under change of pressure and temperature.
    a. What constitutes a gas; a liquid; a solid.
    b. The liquefaction of air in the light of the kinetic molecular theory of matter.
    Practical application of the liquefaction of air and of other gases.

C. Nitrogen and its common compounds.

1. Recall that the atmosphere is the source of nitrogen.
2. Class discussion of the importance and economic value of nitrogen.
3. Compounds of nitrogen.
    a. Ammonia.
        (1) Uses and economic value.
        (2) Sources.
        (3) Preparation.
        By decomposition of organic matter.
        Ammonia as a product of decay.
        From compounds containing it, by displacement.
        By direct union of hydrogen and nitrogen.
        The Haber process.
        (4) Properties and chemical behavior.
        "Solution" in water.
        Ammonium hydroxide.
        Properties and uses.
        The ammonium radical.
        Ammonium compounds.
        (5) Use of ammonia in artificial refrigeration.
        Study of a refrigerating plant (local).
        (6) Comparison of ammonia with refrigerants used in various household refrigerators.
    b. Important oxides of nitrogen.
        (1) Nitrous oxide.
        Preparation, properties and uses.
        "Laughing gas."

(2) Nitric oxide.
Preparation, properties and uses.
(See sulfuric acid, chamber process)
(3) Nitrogen peroxide.
Preparation, properties and uses.

4. The fixation of atmospheric nitrogen.
   a. By growing plants.
   b. Birkeland and Eyde process.
   c. Calcium cyanamide process.
   d. Importance of fixation to problem of soil fertilizers.

5. Nitric acid.
   a. Economic importance, in connection with manufacture of explosives, dyes, artificial silks, fertilizers, etc.
   b. Details of preparation and manufacture.
      (1) From natural nitrates.
      Chile saltpeter.
      Equations for reactions.
      (2) From atmospheric nitrogen.
      Reaction of nitrogen peroxide with water.
      Refer to sources of nitrogen peroxide. Also, the oxidation of ammonia, obtained by Haber process or by action of steam upon calcium cyanamide.
      (3) Discuss the Muscle Shoals project.
   c. Properties of nitric acid.
      (1) Oxidizing action when concentrated.
      (2) Acid action when diluted.
      (3) Products of nitric acid.
      Nitrates.

6. Elements relation to nitrogen.
   Discuss briefly the chemical resemblances of nitrogen, arsenic, antimony, bismuth and phosphorus.

Block 2. Sulfur and Its Common Compounds

A. Class discussion of the economic importance of this element and of its many compounds. Emphasize the many ramifications of the influence of this element upon the progress of civilization, because of the many ways in which it enters directly or indirectly into our daily life. This element provides us with a good example of the truth that it is not of necessity the substance which is best known to us in our ordinary experience that proves to be the most valuable in our economic scheme of things.

B. Sulfur.
   1. Sources of sulfur.
   Forms of occurrence.
   2. Production of sulfur.
   The Frasch method of extracting sulfur.
   Frasch (biographical).
   3. Properties and chemical behavior.
   Allotropic forms.
   4. Specific uses of the element in industry, in medicine, and in sanitation.

C. Compounds of sulfur.
   1. Hydrogen sulfide.
      a. Occurrence and use of "sulfur springs."
      b. Production of the gas from sulfides.
      c. Properties of the gas.
      Characteristics of an aqueous solution.
      Hydrosulfuric acid.
      Characteristics and uses.

   2. Metallic sulfides.
   Common examples, with discussion of uses and importance of each.

   3. Oxides of sulfur.
      a. The dioxide.
         (1) Importance and general uses.
         (2) Preparation.
         From the element by oxidation.
         From sulfides by roasting.
         From sulfuric acid by action of metals.
         (3) Properties.
         Characteristics of solution in water.
         Sulfurous acid.
         Sulfides.
         (4) Bleaching by use of sulfur dioxide.
         Bleaching by reduction as contrasted with bleaching by chlorine.
      b. The trioxide.
         (1) Production from the dioxide—an example of catalytic action.
         (2) Reaction with water.
         The contact process for the production of sulfuric acid.
         Advantages of the process.
         Difficulties of the process.

   4. Sulfuric acid.
      a. General importance.
      b. Production by the chamber process.
      Sources of the sulfur used.
      Details of the process.
      Study of the main reactions.
      Reasons for the continued supremacy of this process.
      c. Characteristics and properties.
      Anhydrous sulfuric acid.
      Absence of strong acid properties.
      Storage and transportation of concentrated sulfuric acid in iron containers.
      Action of hot concentrated sulfuric acid upon metals and organic substances.
      Oxidation reactions.
      Sulfuric acid in solution.
      Reaction with metals with the production of hydrogen.
      d. Compounds of sulfuric acid.
      Sulfates, normal and acid.
      Common examples, with uses.

D. The sulfur family.
   Refer to selenium and the selenium cell.

Block 3. The Halogen Elements and Fluorine

A. Sources of the halogen elements.
   1. It is suggested that the study of each of these elements be introduced by a consideration of the common uses and the economic value of the element.
   2. Modes of preparation of the halogen elements essentially two:
      a. Oxidation of the binary acid of the element.
      b. Electrolysis of a solution of a salt.
   3. Chlorine.
      a. Economic value and ordinary uses.
      b. History.
         (1) Scheele (biographical).
         (2) Davy (biographical).
      c. Preparation by each of the methods indicated above.
         Details and equations.

         It is most strongly recommended that chlorine be prepared only in minute quantities, if at all, under a proper hood, by high school students. If any quantity of the gas is to be prepared or collected in vessels, it should invariably be done by the instructor, personally.
      d. Properties and chemical behavior of the element.
         Direct combination with other elements.
      e. The manufacture of bleaching powder.
      f. Use in the purification of water.
      g. Use as a bleaching agent.
         (1) The release of nascent oxygen from water.
         (2) The necessity for thorough washing of fabric after bleaching.
      h. The Carrel-Dakin solution.
      i. The commercial production and handling of chlorine.
   4. Bromine.
      a. Economic value of ordinary uses.
      b. Preparation of the element by each of the general methods indicated for halogens.
         Details of preparation with equations.
      c. Properties and behavior of the element.
      d. Compounds of importance in medicine and in photography.
   5. Iodine.
      a. Economic value and ordinary uses.
      b. Preparation of the element from its compounds.
   6. Summarize the likenesses and differences of the halogen elements.
      a. Compare the relative chemical activities of these elements.
      b. The displacement series of the halogens.
      c. Discuss the halogen elements as members of a representative family of elements.
   7. Fluorine.
      a. Discuss the most important compounds of this element.
      b. Uses for compounds of fluorine.

B. Photography, its chemical nature and applications. (Optional)
   1. The place of photography in modern life.
   2. The effects of energy in the form of light applied to certain substances.
      a. Refer to the function of light energy in the formation of starch in the green leaves of plants.
      b. The effect of light energy upon a mixture of hydrogen and chlorine gases.
      c. The effect of light energy applied to halogen compounds of silver.
         (1) Influence of presence of organic matter in contact with the silver salt.
         (2) Compare the action of certain reducing agents (developers), upon halogen compounds of silver which have been exposed to light and upon those which have not been so exposed.
   3. The materials of photography.
      a. The sensitized film.
         (1) Material of the film.
         (2) The process of sensitizing the film.
      b. Developers, general characteristics.
         (1) Act as reducing agents.
         (2) Types and examples.
         (3) Materials used in making developing solutions.
      c. Fixing solutions.
         (1) The purpose of the fixing solution.
         (2) The materials of the fixing solution.
         (3) The necessity for thorough washing of the film after fixing.
   4. Print papers.
      a. Types of papers commonly used.
      b. Materials with which papers are coated and sensitized.
      c. Methods for production of a permanent print.
   5. Moving picture film.
      Explosive and non-explosive "celluloid."

Block 4. Phosphorus and Its Compounds

A. Phosphorus.
   1. Economic importance and uses.
   2. Sources of the element.
   3. The preparation of phosphorus from its compounds.
      Equations for reactions involved.
   4. Allotropic forms.
      Allotropism.
   5. Properties of the element.

6. The match industry.
   a. Friction matches.
      Dangers in handling white phosphorus.
   b. Safety matches.

B. Compounds of phosphorus. (Oxides and acids)
   1. Phosphates.
      a. Insoluble and soluble calcium salts of phosphoric acid.
      b. Need of soluble calcium acid phosphate for fertilizer.
      c. Preparation of phosphate fertilizers.
      d. Use of sodium acid phosphate in baking powder.
   2. Phosphorus sesquisulfide.
      Safety matches.

Unit V.

Block 1. Carbon a Constituent of all Life Compounds—Foods

Existence of carbon compounds throughout all living forms of plant and animal life may well be stressed at this point.

A. Chemistry of foods and nutrition.
   1. What constitutes a food?
   2. Classes of food substances, with examples.
      a. Carbohydrates, fats, and proteins.
      b. What each class of food brings to the body.
   3. The necessity for digestion of foods.
      a. Characteristics of salivary digestion. Active digestive ferments in saliva.
      b. Characteristics of stomach digestion. Active digestive agents in the stomach.
      c. Characteristics of intestinal digestion. Active digestive agents in the intestinal tract.
   4. How foods get into the blood stream. Assimilation.
   5. The simple principles of utilization of cell tissue to produce heat and motion in the body.
      a. The body considered as a power plant.
      b. Products of destruction of cells in the body.
         Disposal of products of cell destruction.
   6. The determination of values of foods. Use of the calorimeter.
   7. Discussion of balanced diets.
      a. Study of the amounts of various foods necessary to maintain health.
      b. Vitamines.
   8. Testing the purity of foods. Food preservatives, good and bad.
   9. The chemistry of decay. Use of refrigeration in warehouse, store and home.

B. Chemistry in the household.
   1. Cooking.
      a. The purposes of and need for cooking of foods.
      b. Effects of cooking upon different kinds of food materials.
      c. Investigation of temperatures at which effective cooking and baking take place.
   2. Leavening agents.
      a. Purpose of the use of leavening agents.
      b. Types of leavening agents.
         (1) Yeast and fermentation.
             Bread making.
         (2) Baking soda and baking powders.
             The chemistry of the action between baking soda and sour milk.
             The chemistry of the action of baking powders.
             Cream of tartar, phosphate, and alum powders.
             Testing of baking powders.
   3. Cooking utensils.
      a. Desirable qualities.
         Discussion of the extent to which different materials in common use meet requirements.
      b. Cleansing agents for different materials used.
   4. Table utensils.
      a. Discussion of the advantages of the use of silver.
      b. Silver substitutes.
      c. Cleansing silver by chemical means.

C. Chemistry in farm and garden.
   1. What the application of the principles and facts of chemistry has done for agriculture within comparatively recent years. Scientific farming.
   2. Food for plants.
      a. The food elements necessary for plant growth.
      b. Control of the amount of food elements in the soil.
         (1) Soil analysis.
         (2) Use of fertilizers to make up deficiencies in soil.
             Choice of fertilizers, as indicated by soil analysis and the demands of the crop to be planted.
         (3) The chemistry of rotating crops.
   3. Food for animals.
      a. Scientific selection of food for animals. Balanced rations for animals.
      b. Sanitation of animals' quarters through chemical means.
   4. Destruction and control of pests and blights.
      a. Insecticides and fungicides in common use.
         (1) Preparation and use of lime sulfur spray.
         (2) Preparation and use of lead arsenate solutions.
         (3) Investigation of other compounds and mixtures in use in the community.

D. Chemistry and the advance of medicine.
   1. The purposes, in general, for which drugs are used.
   2. The sources of the materials of medicine.
   3. Metallic compounds commonly used in medicine.
   4. The purification of drugs by chemical means.
      The isolation of active principles and the elimination of undesirable or poisonous substances commonly associated with crude natural drugs.
   5. The manufacture of synthetic or coal tar drugs.
   6. The place of chemistry and its products in sanitation as a means for the control and elimination of disease.

Block 2. Fuels

Discussion of the importance of the knowledge and use of fuels in the growth of civilization.

A. The general purposes of fuels.

B. Desirable characteristics of fuels; the basis of selection of fuels.

   Convenience, reliable supply economy, absence of undesirable impurities, low ash, high heat value.

C. Carbon, the basic element in all fuels in general use.
   1. Class discussion of the importance of carbon in the living world.
   2. The natural forms of pure carbon.
      a. The diamond.
      b. Natural sources.
      c. The production of artificial diamonds.
      d. Moissan and the electric furnace (biographical).
      e. Uses of the diamond.
   3. Graphite.
      a. Natural sources.
      b. Production of artificial graphite.
      c. Common uses for graphite.

D. The products of the combustion of carbon.
   1. Carbon dioxide.
      a. Equation for the combustion of carbon to the dioxide.
      b. Properties of carbon dioxide.
      c. Uses of carbon dioxide.
         The chemical fire extinguisher.
      d. The solution of carbon dioxide in water.
         (1) Properties of the solution.
         (2) Products of the action of this solution.
            (a) Carbonates.
            (b) Soluble bicarbonates.
               The formation of limestone caves.
      e. Sources of carbon dioxide other than the combustion of carbon.
         Action of acids on carbonates.
   2. Carbon monoxide.
      a. Conditions of formation of this gas in furnaces and stoves.
      b. Value as a reducing agent.
      c. Poisonous qualities.
         (1) The danger in stoves and furnaces without proper flue connection.
         (2) Properties of carbon monoxide.
         (3) The danger in the exhaust gases of an automobile engine.

E. Most widely used fuels.
   1. Coal.
      a. All forms of coal impure forms of carbon.
      b. The history of the use of coal.
      c. The story of the formation of coal.
      d. Kinds of coal.
         Difference in properties and characteristics of soft (bituminous) and hard (anthracite) coal.
      e. Coke.
         (1) Cooking methods. The wasteful beehive oven; gas retorts; the by-products coke oven.
         (2) The importance of the conservation of the supply of coal in the manufacture of coke.
         (3) Valuable by-products obtainable from coal in the manufacture of coke.
   2. Fuel gases.
      a. Natural gas.
         (1) Methane, the chief constituent.
         (2) Sources and production of natural gas.
         (3) Economic importance of natural gas.
         (4) Means for conserving the supply of natural gas.
      b. Illuminating gas.
         (1) Method of production.
         (2) Valuable by-products of the process.
      c. Producer gas.
         (1) Method of production.
         (2) Importance of this gas to industry.
      d. Water gas.
         (1) Method of production.
         (2) Dangers in the use of this gas.
      e. Acetylene.
         (1) The manufacture of calcium carbide.
            The reactions of the formation of this product.
         (2) The preparation of acetylene.
            Equations for formation.
         (3) Properties.
         (4) Use in cutting and welding of metals.
            Explanation of the high temperature to be obtained in the combustion of acetylene.
         (5) Thermal equations.

3. Fuel oils.
   a. Sources of fuel oils.
   b. Chief constituents of fuel oils.
      Nature of hydrocarbons.
   c. Economic importance of fuel oils.
   d. The fractionations of fuel oils.
      Valuable products.
   e. "Cracking" of oils.
   f. Desirable characteristics of a motor fuel.
      (1) Discussion of the use of substitutes for gasoline as motor fuel.
      (2) Use of oils as solvents.

F. The measurement of heat.
1. The calorie.
2. The calorimeter.

Block 3. Organic Acids, Bases and Salts (Esters, Alcohols and Soaps)

A. The structural formula and its use in organic chemistry.

B. Organic acids.
1. Some common organic acids.
   a. Acetic.
   b. Tartaric.
   c. Malic.
   d. Citric.
   e. Lactic.
   f. Butyric.
   g. Oleic.
   h. Palmitic.
   i. Stearic.
2. Occurrence and preparation of most common organic acids.
3. Properties and uses.

C. The alcohols.
1. Occurrence and preparation.
2. Structure and characteristics.
3. More common examples and their uses.
   a. Ethyl.
   b. Methyl.
   c. Denatured.
   d. Glycerol or glycerine.
   e. Cholesterol.
      Occurs commonly in egg yolk and nervous tissue.

D. Aldehydes.
1. Structure and characteristics.
2. Preparation.
3. More common examples and their uses.
   a. Formaldehyde.
   b. Acetaldehyde.

E. Soaps.
1. Types and composition.
2. Preparation of commercial soaps.
3. By-products in soap manufacture.
4. Properties and uses of soaps.

F. Esters.
1. Definition and chemical composition.
2. Common examples of esters and their uses.
   a. Fats and vegetable oils.
   b. Waxes.
3. Hydrogenation of oils.
   Crisco.

Unit VI.

Block 1. Solutions

A. Informational.

1. Solvent—
   - (a) Most common—water.
   - (b) Other solvents—(alcohol, varnish, shellac) Naptha ether (carbon tetra-chloride—grease) dry cleaning.
2. Solute—the dissolved substance.
3. Types of solutions:
   - (a) solid in liquid—salt and water
   - (b) solid in solid—alloys
   - (c) solid in gas—smoke
   - (d) liquids in liquid—alcohol in water
   - (e) liquids in solids—water of crystallization
   - (f) gases in gases—air
   - (g) gas in liquids—oxygen in water
   - (h) gases in solids—occluded gases in metals (charcoal in gas masks)
4. Classes of solution:
   - (a) saturated
   - (b) supersaturated
   - (c) unsaturated
   - (d) saturated vs. concentrated solutions
5. True solutions vs. colloidal suspensions or dispersions. Brownian movements in colloidal solutions.
6. Colloids.
   - (a) kinds of colloids
     1. Suspensions
        - a. absorption
          - a_2 gels (effect of pectin in production of gels)
     2. Emulsions
   - (b) Manufacture of colloids
     1. Guiding to fine powder
     2. Electric arc under water-gold, platinum, cadmium
     3. Discharge of Rumkorff coil in gold chloride solution
     4. Hydrolysis of sal
     5. Addition of large excess of one reagent
   - (c) Breaking down of colloids
     1. Physical
        - a. heat
        - b. cottrell process
     2. Chemical
        - a_2 acids
        - b_2 Ensyme
7. Absorption.
   - (a) cleansing power of soap
   - (b) water purification

B. Experimental.

1. Solutions of water soluble substances—concern shown when substance is not water soluble.
2. Solutions of alcohol, rosin, etc.
3. Saturated, undersaturated, supersaturated solution of some salt.
4. Variable solubility of salts.
5. Effect of removal of pressure on solubility of gases in liquids in a bottle of carbonated water.
6. Ray of light through a suspension vs. a clear solution.
7. Making of mayonnaise dressing—water-oil-soap emulsion.
8. Colloidal gold by electric arc.
9. Coagulation of egg albumin by heat.
10. Clarification of a muddy water suspension by aluminum hydroxide.
11. Testing for an oil-water or water-oil emulsion.
12. Making a colloidal solution of arsenious sulfide.
13. Solid alcohol.
    - (a) Calcium acetate and alcohol gel.
14. Brownian movement observation.
15. Osmotic pressure with thistle tube and membrane.
16. Making a collodion tube in a test tube.
17. Normal and molar solutions.

Block 2. Ionization

A. Informational.

1. Water a nonconductor of electricity.
2. Aqueous, sugar and alcohol nonconductors of electricity.
3. Electrolytes and nonelectrolytes.

4. Effect of sugar solutions (molar) and salt solutions (molar) on boiling point.
5. Theory of Arrhenius.
6. Explanation of electrolysis.
7. Ionization as shown by centrifuge.
8. Protons and electrons.
9. Degree of ionization possible.
10. Ions and color identifications of solutions.
11. Replacement series.
12. Neutralization, hydrolysis and mass action in terms of ionization.
13. Ionic equilibrium and completion reactions.
14. Speed of chemical reactions.

B. Experimental.

1. Making a standard, normal and molar solution.
2. Determine per cent of acidity by means of a standardized solution, also per cent of alkalinity.

a. Use of formula

$$\% = \frac{\text{CC used x Normality x H equivalent x 100}}{\text{Wt. taken x 1000}}$$

b. To determine No. of CC needed to make a standard or solution of certain normality

$$CC = \frac{\text{M. W.}}{\text{sp. Gr x \% Strength x H equivalent x Normality desired, in terms of decimals}}$$

e. g. To make a .10 normal solution of H_2SO_4

$$CC = \frac{98}{1.80 \text{ x } .96 \text{ x } 2 \text{ x } 10}$$

c. Electrolysis of water, copper sulfate.

3. Electrolysis of solution of common salt.
4. Sour taste of acids.
5. Liberation of hydrogen upon action of HCL on zinc.
6. An iron nail in copper sulfate.
7. Effect of heat on chemical reaction.

UNIT VII.

Block 1. Matter—The Electron Theory

A. 1. Dalton's Atomic Theory.
   a. Law of definite proportions.
   b. Law of multiple proportions.
2. The periodic classification.
3. The proton.
4. The electron.
5. Isotopes.
6. Atomic numbers.
7. Radioactivity as distinguished from chemical change.
   a. effect of heat.
   b. effect of pressure.
   c. effect of light.
   d. effect of concentration.

B. Valence in terms of the electron theory.

C. Equations:—
1. Types of reactions.
   a. Direct combination
      (1) $2H_2 + O_2 \rightarrow 2H_2O$
      (2) $H_2 + Cl_2 \rightarrow 2HCl\uparrow$
   b. Decomposition
      (1) $2H_2O \rightarrow 2H_2 + O_2\uparrow$
      (2) $2KClO_3 \rightarrow 2KCl + 3O_2\uparrow$ or $2\ KClO_3 + MnO_2 \rightarrow 2KCl + 3O_2\uparrow + MnO_2$
   c. Simple replacement
      (1) $Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$
      (2) $2Na + 2HOH \rightarrow 2NaOH + H_2\uparrow$
      (3) $H_2 + CuO \rightarrow H_2OCu$
      (4) $Zn + CnSO_4 \rightarrow ZnSO_4 + Cu$
   d. Double decomposition
      (1) $HCl + NaOH \rightarrow NaCl + HOH$
      (2) $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$
2. Reactions that go to completion.
   a. Those in which one of the products is a gas.
   b. Those in which one of the products is an insoluble substance.
   c. Those in which one of the products is nonionizable or only slightly ionizable.

D. Demonstrate that the law of the conservation of matter is the fundamental principle involved in equation writing.
1. Write an equation.
   a. First as a skeleton.
   b. As a balanced equation.
2. Demonstrate by passing H_2 over known weight of heated CuO.
3. Mass is the same on both sides.
4. When the product of a reaction is a gas demonstrate the fact that an equation shows both mass and volume phenomena.
5. An arrow is used instead of an equality sign because of the nature of the "equation."
6. Double arrows indicate chemical equilibrium.
7. Products are indicated sometimes as gaseous or insoluble by direction of arrows: "UP" being gaseous; "DOWN" being insoluble.
8. Demonstrate Gay-Lussac's Law of Volumes, using:—
   a. H_2 and O_2
   b. N_2 and H_2
   c. CO and O_2
   d. Show by an equation that the coefficients express volume ratios.
   e. The equation expresses conservation of mass but not conservation of space.

E. Equations are empirical because:—
1. Masses of substances involved are accounted for.
2. Substances most frequently in aqueous solutions yet water not considered unless acted upon in reaction.
   Energy (heat, light or electricity).
3. Heat, light or electricity involved not generally accounted for in equation writing.

F. The volume of a gas.
1. Effect of pressure change upon a gas.
   a. The volume decreases as the pressure increases.
      Illustration—to compress the air in a tire pump requires pressure.
   b. Gas pressure in terms of barometric height.
      New volume (V^1) = old volume (V) x a fraction.
      (The fraction is the inverse ratio of the pressure given to the pressure applied.)
2. Effect of temperature change on a gas.
   a. The volume varies according to the absolute scale of temperature.
      Conversion of centigrade into absolute scales of temperature.
      Illustration—tires "blow out" on hot days or when heated by friction in races or when turning corners at excessive speeds.
   b. Application of volume to temperature change according to equation.
      New volume (V^1) = old volume (V) x a fraction.
      NOTE: The fraction is a ratio of the old temperature (absolute) to the new temperature (absolute).
3. Simultaneous effect of temperature and pressure changes upon the volume of a gas. Charles and Boyle's Law.

a. New volume = old volume (Pressure ratio x (temperature ratio). (Pressure ratio and temperature ratio expressed as fractions.)

G. Calculations depending on knowledge of atomic weights.

1. molecular weights
2. per cent composition
3. problems on equations
   a. weight
      (1) Write balanced equations.
      (2) Find molecular weights involved and place below formulae.
      (3) Form proportions requiring ratios only between like things.
   b. volume
      (1) Write equations.
      (2) Find molar volumes of gases involved.
      (3) Form proportions requiring ratios only between like units.

BIBLIOGRAPHY

A small group of well selected textbooks and other reference material will be found to be essential if one is to give pupils an opportunity to supplement their regular class work or even to borrow when the chance is offered. The following list will be found helpful. This list may be greatly extended and enriched by bulletins, catalogs, books, magazines and advertising literature from the better firms.

Textbooks and Other Works on Chemistry

THE CHEMIST ANALYST—J T. Baker, Chemical Company.
BROWNLEE AND OTHERS—Chemistry of Common Things, Allyn and Bacon Co.
BROWNLEE AND OTHERS—Principles of Chemistry, Allyn and Bacon Co.
BLACK AND CONANT—Practical Chemistry.
FLETCHER, SMITH AND HARROW—Beginning Chemistry, American Book Co.
GORDON—Introductory Chemistry, World Book Co.
GORDON—College Chemistry, World Book Co.
GRAY, SANDIFUR AND HANNA—Fundamentals of Chemistry.
GREER AND BENNETT—Chemistry for Boys and Girls, Allyn and Bacon Co.
HOLMES AND MATTERN—Elements of Chemistry, Macmillan Co.
KENDALL—Smith's Elementary Chemistry, Century Co.
LASSAR-COHN—Chemistry in Daily Life, J. B. Lippincott Co.
MCPHERSON AND HENDERSON—Chemistry and Its Uses, Ginn and Co.
MELLOR, J. W.—Comprehensive Chemistry, Longmans, Greene and Co.
MELLOR, J. W.—Modern Inorganic Chemistry, Longmans, Greene and Co.
MORNEWECK—Unpublished Doctor's Dissertation, University of Pittsburgh, 1930.
NEWELL—A Brief Course in Chemistry, D. C. Heath Co.
SMITH, ALEX—College Chemistry, The Century Co.
SMITH, ALEX—General Inorganic Chemistry, The Century Co.

Special Subject References

BACON AND HAMOR—American Fuels, McGraw-Hill Co.
BAILEY, E. H. S.—A Textbook of Sanitary and Applied Chemistry, The Macmillan Co.
BANCROFT—Applied Colloid Chemistry, McGraw-Hill Co.
BORSCHERS-MCMILLAN—Electric Smelting and Refining, C. Griffin and Co.
JONES, H. C.—The Nature of Solution, D. Van Nostrand Co.
LINCOLN—Physical Chemistry, D. C Heath and Co.
MASON—Examination of Water, John Wiley and Sons.
OLSEN, J. C.—Pure Foods, Ginn and Co.
RAMSAY, SIR W.—Gases of the Atmosphere, The Macmillan Co.
ROGERS, ALLEN—Industrial Chemistry, D. Van Nostrand Co.
SHERMAN, H. C—Chemistry of Food and Nutrition, The Macmillan Co.
THORP, F H. AND LEWIS, W. K.—Outlines of Industrial Chemistry, The Macmillan Co.
TOWER, W. S.—The Story of Oil, D. Appleton Co.
VENABLE, F. P.—The Study of the Atom or the Foundation of Chemistry, The Chemical Publishing Company, Easton, Pa.

Other Books Suitable for a School Library

BERRY, PAULINE G.—Chemistry Applied to Home and Community, J. B. Lippincott Co.
CALDWELL AND SLOSSON—Science Remaking the World, Doubleday, Doran and Co.
CRESSY, EDWARD—Discoveries and Inventions of the Twentieth Century, E. P. Dutton and Co.
CUSHMAN, A. S.—Chemistry and Civilization, Richard C. Badger, Boston.
DUNCAN, R. K.—Chemistry of Commerce, Harper and Bros.
DUNCAN, R. K.—Some Chemical Problems of Today, Harper and Bros.
DUNCAN, R. K.—The New Knowledge, Harper and Bros.
FABRE, J. H. C.—The Wonder Book of Chemistry, The Century Co.
GREGORY, R. A.—Discovery the Spirit and Service of Science, The Macmillan Co.
HAMOR, W. A —The Science History of the Universe, The Current Literature Publishing Co., New York.
HENDRICK, E.—Everyman's Chemistry, Harper and Bros., Modern Science Series, N. Y.
JOHNSTON, J. F. W.—Chemistry of Common Life, D. Appleton Co.
LEFEBURE, V.—The Riddle of the Rhine, Chemical Foundation, Inc.
SLOSSON, E. E.—Creative Chemistry, The Century Company.
SLOSSON, E. E.—Chats on Science, The Century Co.
SLOSSON, E E.—Keeping up with Science, Harcourt, Brace and Co.
TILDEN, SIR W. A.—Chemical Discovery and Invention in the Twentieth Century, E. P. Dutton and Co.

Handbooks and Periodicals

Handbook of Chemistry and Physics, The Chemical Rubber Co., 1900 West 112th Street, Cleveland, Ohio.
Spon, E. and F. A.—Bayley's Chemists' Pocket Book, London, S-W. 1, England.
The Scientific American, 29 West 40th Street, New York
School Science and Mathematics, 1439 14th Street, Milwaukee, Wisconsin.
The Journal of the American Chemical Society, Mills Building, Washington, D. C.
Journal of Chemical Education, 20th and Northampton Streets, Easton, Pennsylvania.
Chemistry Leaflets, Department of Chemistry, The Pennsylvania State College, State College, Pennsylvania.

Appendix A.

The Science Laboratory—Classroom

In all of the smaller secondary schools the science classroom and laboratory can be effectively combined. In fact, in many of the larger schools there is a definite trend toward a combined classroom and laboratory. Such a science room permits the instructor to give demonstrations, hold laboratory work, direct reference reading, and hold class discussions as the need arises, at any time during the science teaching period. This eliminates the fixed laboratory and recitation schedule, and thereby provides for a much more effective type of instruction to be done at a specified time and at no other.

A room approximately 22 feet by 42 feet makes possible a very satisfactory arrangement of pupils' tables, demonstration table, and chairs for use in recitation. A very good plan is to have the instructor's table at one end of the room, with blackboard and projection screen behind it. Immediately in front of this demonstration table is a sufficient number of table-arm chairs for use by the pupils during recitation and during demonstrations by the teacher.

At the rear of the room are to be found the students' tables for use in performing the individual laboratory work. In planning the arrangement of the room, due attention must be given to the matter of securing the best natural light. The windows should be at the left of the pupils as they face the instructor's table. The equipment of the science room should be planned with great care. Another satisfactory layout provides for tables seating two pupils, either separate or in unit arranged in the form commonly known as the Lincoln type table.

In the larger secondary schools where there is a sufficient number of students to make possible full use of a chemistry laboratory, this room should conform to model requirements and should be sufficiently large to provide ample working space for the number of pupils who are assigned to the room for laboratory purposes.

It is essential that the architect consider the type of furniture that is to be included in a science room when planning the building. This is necessary to avoid the difficulties which arise when water connections, drain and electrical and gas connections must be made after the building has been completed.

Laboratory table tops are usually made of wood or soapstone, although other composition materials are frequently used. The wood top that seems to serve most efficiently is made of three or four-inch strips of hard birch, put together with a glued tongue-and-grooved joint. The top should be from one to one-and-a-half inches in thickness.

The following formula for acid-proofing wood tops is taken from page six, Bulletin No. 27, 1922, United States Department of the Interior, Office of Education, Washington, D. C. Laboratory Layouts for High School Science:

Solution 1—Black acid-proof finish

1½ lbs. copper sulphate
1½ lbs. chlorate potassium
2 gals. rain water, and boil until dissolved
Always apply this solution hot.

Solution 2—Black acid-proof finish

3 qts. hydrochloric acid
1 qt. aniline oil
2 gals. rain water, and mix
Add ¼ pint of solution No. 1 to this solution to make a better black stain
Always apply this solution cold.

Directions for applying acid-proof solution:

Apply solution No. 1 hot, with a stove brush. Heat this solution by steam or hot water, not over a fire.

Let dry about 4 or 5 hours, then apply solution No. 2 cold and let dry for about 6 hours. Then apply solution No. 1, hot again, and let dry 6 hours. Then apply solution No. 2, cold again. Let this dry for 10 hours. Then oil the tops with half naphtha and half boiled linseed oil and let dry for 3 hours. Then scrape with a steel scraper, taking care not to cut through to show the white wood. Rub with steel wool, sand smooth with fine sandpaper, and apply prepared paraffin with a brush, hot, and rub off with sea moss or rags.

BIOLOGY

The School Buildings Division of the Department of Public Instruction has prepared a suggested layout for a Biology room. The special facilities which should be considered are: Demonstration desk, pupil tables each accommodating 3 or 4 pupils, supply cases, microscope case, sink, window shelves, notebook case, provision for aquarium and terrarium facilities, and projection facilities.

(As indicated in the suggested layout, a Biology room should be approximately 22 x 42 feet. A museum case for the display of specimens is particularly desirable and should be provided in all rooms for Biology.

PHYSICS

The particular things to keep in mind in a Physics Laboratory are demonstration tables, pupil tables, and supply cases. The Physics room can be developed either by having tables and chairs in the front or by combined class and laboratory tables. Where the room is used for classroom purposes, all pupils should face the front. Physics tables are usually equipped with gas and electricity. It is very desirable to have a storeroom adjacent to the room, if possible. The School Buildings Division of the Department of Public Instruction has prepared a suggested layout for a Physics room.

CHEMISTRY

A combined chemistry classroom should be approximately 42 feet in length. The type of furniture will depend upon whether the room is used for other subjects in addition to chemistry. The number of fume hoods will depend somewhat on the ventilation of the building. At least one or two fume hoods should be provided in all laboratories. Provision should be made for a balance shelf or table approximately 8 feet long. Adequate storage space is also essential. It is necessary that water, gas and electricity

should be provided for all tables. The School Buildings Division of the Department of Public Instruction has prepared a suggested layout for a Chemistry room.

LABORATORY USED FOR ALL SCIENCE CLASSES

In a number of schools it is necessary to utilize one room for all science classes. Where this is done care must be used both in planning the room and in selecting the furniture. The items which should be provided in a combination laboratory used for Biology, Physics, and Chemistry are:

Thirty tablet arm chairs adapted for classroom use.

Six combination physics, chemistry, and biology tables or combination laboratory and classroom equipment with seating space for thirty pupils.

Instructor's demonstration desk.

Window shelf.

Balance shelf.
Storage cabinet or closet.
Physics storage case.
Chemistry storage case.
Biology storage case.
Key cabinet.
Fume hood.
Notebook case.
Aquarium.
Germinating bed.
Teacher's desk.
Chart case.
Filing cabinet.
Teacher's closet.
Laboratory sinks.
Screen projection stand.
Cork display board.
Map rack.
Work bench with appropriate tools.

APPENDIX B.

Visual—Sensory Aids in the Field of Science*

Visual-sensory aids are used more widely and contribute more to mastery in senior high school science than perhaps to any other subject in the curriculum. Effective procedure in this field utilizes all the senses—seeing, handling (feeling), hearing, smelling, tasting; and in this connection, when using the visual sense it is well for instructors and students to remember that observation involves more than looking at something—it means not only seeing but interpreting. This is true in using the microscope as well as the naked eye.

Modern procedure in high school science requires the almost constant use of the major visual-sensory aids—apparatus and equipment, school journeys or field trips, objects-specimens-models, and pictorial materials. Effective procedure involves a thorough knowledge of these aids—their values, sources, guiding principles for use, and a mastery of their techniques.

Apparatus and Equipment include the blackboard, bulletin board, maps and charts, projectors, models, pictorial files, instruments, and the devices necessary to make instruction meaningful. From the professional and economic viewpoints, it is very essential that instructors know standards for evaluating apparatus and equipment. Lack of this knowledge has resulted in an accumulation of inferior and unnecessary materials in many school districts. Since apparatus and equipment are essential classroom tools, it is highly important that teachers know the minimum equipment of standard apparatus necessary for the teaching of the various science subjects. Resourceful teachers will be able to assemble and to have pupils make considerable valuable material. This procedure will be an asset to the science classes. The visual education instructors at the State Teachers Colleges have set up minimum standard equipment for science, as follows:

I. Apparatus and Equipment
   See Department Projector Sheet.
   See Department Minimum Standard Equipment Outline.

II. Exhibit
   J. V. Ankeney, Dept. of Education, Charleston, West Virginia.
   State Teachers College, Science Department, Mansfield.
   The A B C of Exhibit Planning, Routzahn—R. Sage Foundation, N. Y. City.

III. School Journey or Field Lesson
   See Department School Journey Bulletin, Vol. I, No. 6.

IV. Object-Specimen-Model
   See Department Object-Specimen-Model Bulletin, Vol. I, No. 8.

V. Pictorial Materials:

Glass Slides—

Cambridge Botanical Supply Co., Waverly, Mass.
Denoyer-Geppert Co., 5235-57 Ravenswood Ave., Chicago
General Biological Supply House, 761 E. 69th Place, Chicago
Keystone View Co., Meadville, Penna.
N. Y. Biological Supply Co., 34 Union Square, N. Y. City
Pilgrim Photoplay Exchange, 804 S. Wabash Ave., Chicago
Spencer Lens Co., Buffalo, N. Y.
State Library and Museum, Harrisburg, Penna.
Victor Animatograph Co., Davenport, Iowa.
Williams, Brown and Earle, 918 Chestnut St., Philadelphia, Penna.

Film Strip—

Atlas Educational Filmslide Co., 5 N. Wabash Ave., Chicago
General Biological Supply House, 761 E. 69th Place, Chicago
McIntosh Stereopticon Co., 549 W. Randolph St., Chicago
Muir Co., James C., 10 S. 18th St., Philadelphia
N. Y. Biological Supply Co., 34 Union Square, N. Y. City
Pilgrim Photoplay Exchange, 804 S. Wabash Ave., Chicago
Society for Visual Education, 327 S. LaSalle St., Chicago
Spencer Lens Co., Buffalo, N. Y.
Still Film Co., 25 Third Avenue, N. Y. City.
Victor Animatograph Co., Davenport, Iowa
Williams, Brown and Earle, 918 Chestnut St., Philadelphia

*This section prepared under the direction of C. F. Hoban, Director of Visual Education.

Films—(Most of the following are supplied in 16mm. and 35mm.)

Bell and Howell, 11 W. 42nd St., N. Y. City
Bray Productions, 729 Seventh Ave., N. Y. City
Carpenter-Goldman Laboratories, Inc., 161-179 Harris Ave., Long Island, N. Y.
Carter Cinema Producing Corp., 551 Fifth Ave., N. Y. City
Eastman Teaching Films, Inc., 343 State St., Rochester, N. Y.
Film Classic Exchange, 265 Franklin St., Buffalo, N. Y.
Ford Motor Picture Laboratories, Detroit, Mich.
Fox Film Corp., 850 Tenth Ave., N. Y. City.
General Electric Co., Schenectady, N. Y.
Herm, Chas. F., Daytona Beach, Florida.
Herman Ross Enterprises, Inc., 622 Ninth Ave., N. Y. City
Ideal Pictures Corp., 26 E. Eighth St., Chicago
National Cash Register Co., Dayton, Ohio.
N. Y. Zoological Society, Boro of Bronx, N. Y. City
Pathe Exchange, Inc., 35 W. 45th St., N. Y. City
Q. R. S.—De Vry Corp., 131 W. 42nd St., N. Y. City
Rothacker Film Corp., 7510 N. Ashland Ave., Chicago
United Projector and Film Corp., 228 Franklin St., Buffalo, N. Y.
Visual Education Service and Supply Co., 115 N. Pennsylvania St., Indianapolis, Ind.
Yale Chronicles, Yale University Press, 522 Fifth Ave., N. Y. City
Y. M. C. A., 120 W. 41st St., N. Y. City
See "1000 and One"—Educational Screen, Chicago
See *Enriched Teaching of Science in the High School* Woodring-Oakes-Brown, Teachers College, Columbia University, N. Y. City

Maps, Charts, Graphs—

Denoyer-Geppert Co., 5235-57 Ravenswood Ave., Chicago
N. Y. Biological Supply Co., 34 Union Square, N. Y. City
Nystrom and Co., A. J., 3333 Elston Ave., Chicago
Rand McNally Co., 536 S. Clark Ave., Chicago.
Scribner, 597 Fifth Ave., N. Y. City
U. S. Dept. of Agriculture, Washington, D. C.
See also—*Enriched Teaching of Science in the High School,* Woodring-Oakes-Brown, Teachers College, Columbia University, N. Y. City

Pictures, Posters—

National Association of Audubon Societies, 1974 Broadway, N. Y.
National Child Welfare Association, 70 Fifth Ave., N. Y. City
National Geographical Society, Washington, D. C.
Perry Pictures Company, Malden, Mass.

VI. Plays, Clubs, Projects—

See *Enriched Teaching of Science in the High School* Woodring-Oakes-Brown, Teachers College, Columbia University, N. Y. City

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The School Journey or Field Trip is a fruitful medium for high school science work since it brings students to botanical gardens, arboretums, bird sanctuaries, zoological parks, fish hatcheries, orchards, cattle and poultry farms, experimental laboratories, museums, industries and the places where practical applications of science are made.

In addition to the school laboratory, the world must be the laboratory of science classes. This puts students in direct touch not only with nature but with the application of scientific principles to the economic and social organizations. Further, it provides the realistic and concrete elements so necessary to a thorough understanding of science. It becomes necessary then for teachers to know how to organize, conduct, and check school journeys or field trips. For this purpose, they should have a copy of the School Journey Bulletin which may be procured from the Visual Education Division, Department of Public Instruction.

Live materials are central objects of study in this subject; mounted and preserved specimens are very essential; models also have a large place in the instructional and learning procedures. The journeys or field trips will offer opportunities for securing these materials. It will also be necessary to draw upon commercial houses, museums, laboratories, and other such institutions. Much material may be gathered through exchange arrangements. Students appreciate object-specimen-model collections that they themselves assemble and develop, more so than those provided in other ways. Interest is the key that unlocks the door to self-activity. Self-activity, in turn, sets at work initiative; this gives opportunity for genius and originality to express themselves. Again it becomes necessary for teachers to know where to get these materials, and when and how to use them. Thus it will be seen that technique is an indispensable part of teacher preparation.

But school journeys or field trips and objects-specimens-models are not enough. Pictorial materials—flat pictures, standard size slides, microscopic slides, and motion picture films are requisites for effective work. The microscope and X-ray reveal things that are hidden to the naked eye. But the X-ray is not always at hand. The photographic image of any revelation becomes the important substitute. Again, the motion picture penmits one to penetrate to the depths, to look inside, and to see in motion actions and movements that otherwise are unrevealed; it also brings distant scientific information to teachers and students. Because of these facts, pictorial materials are an important asset.

It is well to repeat that every science teacher should have access to a good still projector with microscopic attachment and a motion picture machine—preferably the 16 mm. type. Of the utmost importance is adequate storage for apparatus and equipment. These facilities are necessary to insure proper care, safety, and availability.

Science teachers should have a carefully selected collection of pictorial materials, systematically arranged, and ready for use at the proper time. Two examples of the systematic collection of materials given in this bulletin include the treatment of charts and posters in the teaching of Chemistry, and a list of films and slides for high school Chemistry.

CHARTS AND POSTERS*

Much of the visual material listed in the following outline is in the nature of posters. These posters made by the pupils are excellent visual aids and at the same time serve to arouse interest and enthusiasm in the class room. (It is not suggested that any class attempt charts or posters for all units.)

These posters can be assigned to the pupils working in groups or as individuals. Solid materials or liquids used in the making of a poster can easily be placed in small pill bottles which can be obtained from any drug store. Pictures can be cut from discarded magazines and arranged on cardboard. Work of this sort arouses the enthusiasm of the pupil, causes him to go to the library to look up reference material, and when completed serves as an excellent visual aid for the other pupils. Models of chemical processes and industries can frequently be made and embodied in a poster.

Unit I. Block 1. Water the Universal Solvent

Specimens. Different Types of Crystals.
Demonstration. Distillation of Water.

*Prepared by Bruce F. Lamont, Head of Science Department, Hazleton High School.

Posters. General Methods of Water Purification
Showing the Effects of Different Types of Water on Certain Metals
Relative Costs of Softening Water with Different Substances
Hard Waters and How to Soften Them
Soluble and Insoluble Substances
Showing Crystallization from a Saturated Solution of Hypo
Showing Relative Amounts of Different Salts Soluble in Hot and Cold Water

Unit I. Block 3. Hydrogen—the Lightest Element

Posters. Hydrogenation of Oils
Use of Hydrogen in Industry.

Unit I. Block 4. Oxygen

Posters. Chemistry Fighting Fires.
Fire Prevention
Oxygen in Relation to Life
Models. Oxyhydrogen Blowpipe.
Miners safety Lamp.
Journey. To Priestleys Home or Pictures of Priestleys Apparatus.

Unit II. Block 1. A Study of Acids

Chart. Showing All Acids Contain Hydrogen
Poster. Action of Metals on Acids
Use of Acids in Industry.

Unit II. Block 2. A Study of Bases

Chart. Important Bases
Posters. Industrial Uses of Bases
Uses of Bases in Soap
Model. Mounted Samples. Showing What Types of Soap May be Used on different Fabrics.

Unit II. Block 3. Salts

Charts. Metric Chart. Showing Proportional Actual Size of all Metric Measures.
Specimens. Fales Units. Made up of Collection of a Variety of Salts of Many Elements. Fales Company, New York
Chart. Nomenclature of Common Substances.
Posters. Important Salts and Their Uses.
Ways of Preparing Salts.

Unit II. Block 4. (A) Solutions; (B) Ionization; (C) Valence.

Charts. Valence. Elements and Radicals Classified According to Valence and Arranged Alphabetically
Properties of Solutions, Suspension and Colloids.
Posters. Alcohol as a Solvent.
Colloids in Industry.
Colors Produced by Different Salts in Solution.
Model. Construction of Ultra Microscope to Show Colloids.

Unit III. Block 1. Family Relationships and Atomic Numbers.

Models. Models of Various Atoms Showing Structure. Made of Putty or Modeling Clay and Painted in Different Colors and Held together by Wire.
Pouleur Structural Molecular Models. L. E. Knott, Cambridge, Massachusetts
Spectroscope.
Diagrams. Showing Behavior of Electrons. Such as Combining Hydrogen and Oxygen to Form Water.
Relations of Electron and Ionization Theories.

Unit III. Block 2. Purification of Metals.

Model. Electric Arc Furnace.
Posters. Metals Used in the Home.
Use of Metals in Industry.
Metals Used in Automobiles.
Metals Used in an Airplane.
Specimens. Washington School Collection of Minerals. L. E. Knott Company
Chart. Alloy Chart. Showing Metals, Melting Points, and Uses.

Unit III. Block 3. Metals that Touch Our Everyday Life.

(A) Iron-Steel

Specimens. Hematite, Cast iron, Wrought iron, and different grades of steel.
Posters. Making of Cast Iron. Blast Furnace.
Making of Steel.
Bessemer Converter
Some Uses of Steel.
Making of Blue Prints.

(B) Copper

Posters. Copper Sulphate as a Fungicide.
Copper Plating.
Copper Salts in Industry.

(C) Lead

Posters. Industrial Uses of Lead.
Lead Alloys.

(D) Zinc

Posters. Galvanizing Iron.
Uses of Zinc Chloride. Such as Preserving Wood and Soldering.
Alloys of Zinc.

(E) Tin

Posters. Stannous Chloride as a Mordant.
Uses of Tin.

(F) Sodium

Posters. Baking Powders.
Uses of Sodium Compounds.

(G) Calcium

Posters. Building Materials.

(H) Aluminum

Posters. Aluminum in the Home.
Aluminum in Industry.
Aluminum Hydroxide as a Coagulant.

(I) Silver

Posters. Cleaning Silver Ware.
Development of a Photograph.
Manufacture of a film.

(J) Silicon

Posters. Uses of Cement.
Manufacture of Cement.
Making of Glass.
Different Types of Glass.

(K) Radium

Posters. Uses of Radium Paint.

Unit IV. Block 1. The Air and Atmosphere.

Model. Neon Lamp. Barometer.
Posters. Products of Air in War and Peace.
Fixation of Nitrogen.
Nitrogen Cycle.
Refrigeration.
Rare Gases of the Air.
Nitrogen in Agriculture.

Unit IV. Block 2. Sulfur and Its Common Compounds.

Models. Frasch Process and Contact Process, to be made by pupils.

Posters. Uses of Sulfuric acid in Industry.
Sulfur Products.

Unit IV. Block 3. The Halogens.

Journey to Swimming Pool Equipment with Chlorinator.

Posters. Halogens in Medicine.
Chlorine in Water Purification.
Etching Glass.

Unit IV. Block 4. Phosphorus and Its Compounds.

Poster. Manufacture of Matches.

Unit V. Block 1. Carbon, a Constituent of all Life Compounds—Foods.

Models. Fire Extinguishers.
Gas Masks.

Posters. Coal Products.
Coal Tar Products.
Coal Tar Perfumes and Flavors.
The Place of Various Foods in Diet.
Foods Depended Upon For Vitamines.
Purification of Sugar.
Rayon.

Unit V. Block 2. Fuels.

Model. Welsbach Mantle.

Posters. Carbon Monoxide.
Gasoline.
Motor Oils.
Means of Saving Fuel in a House.
Comparison of the calories of heat which may be bought for a dollar in a community using the following fuels: bituminous coal, anthracite coal, wood, kerosene, gasoline, etc.
Manufacture of Artificial Gas.
Fuels Derived from Petroleum.

Unit V. Block 3. Organic acids, Bases, and Salts.

Posters. Manufacture of Soap.
Explosives.
Uses of Alcohol.

Posters of a General Nature

The Alchemist
Chemical Terms in Advertisements
Chemistry Eliminates Waste
Chemistry and Pests
Chemistry in Our Pleasures
Chemistry Means Comfort and Convenience in Our Homes
Chemistry Protects Our Health
Chemistry Aids the Cook
Chemistry for Milady
American Made Dyes
Paints
Removal of Stains
Proper and Improper Garbage Disposal
Fabrics in which Cellulose Silk is Used
Tests For Cotton as an Adulterant of Wool
Home Tests on Fastness to Washing
Home Tests on Fastness to Perspiration
Proper and Improper Methods of Home Dyeing
Artificial Leather
Manufacture of Paper
Hair Tonics
Tooth Powders
Face Powders
Face Creams
Non-Perspirants

Pictures of Prominent Chemists

Bunsen	Liebig	Priestley
Boyle	Lewis	Remsen
Dalton	Langmuir	Richards
Davey	Mendeleeff	Rutherford
Faraday	Moisson	Thomson
Lavoisier	Pasteur	

A chemistry laboratory and classroom may appropriately have any charts and diagrams made by pupils preserved as a part of the permanent collection of visual aids.

FILMS AND SLIDES*

Abbreviations used—For types of aids, M. P., motion pictures; G. S. glass slides, and F. S., film slides. For methods of distribution of slides and films, F, free loan; R, rental for fee, and S, sale. For evaluation, X, for special instruction in class rooms; Y, for general instruction in classrooms; and Z, for general information merely. In the cases of motion picture films, numbers of reels are given in parentheses, (1), (2), etc., and widths are indicated, as 16, for 16mm., 35 for 35mm., and 16-35 for both. All films listed are safety, or slow-burning films. Sources of slides and films are indicated by code numbers, referring to following distributors:

Sources of Films and Slides

1. Ball Brothers, Muncie, Indiana
2. Bray Screen Products, 130 West 46th Street, New York City
3. Bureau of Mines, 4800 Forbes Street, Pittsburgh, Pennsylvania
4. Chilean Nitrate of Soda Bureau, 57 William Street, New York City
5. Combustion Engineering Corporation, 200 Madison Avenue, New York City
6. De Frenes and Company, 60 North State Street, Wilkes-Barre, Pennsylvania
7. Eastman Teaching Films, Inc., 343 State Street, Rochester, New York
8. Edited Pictures System, Inc., 130 West 46th Street, New York City
9. Gas Products Association, Chicago, Illinois
10. General Electric Company, 1 River Road, Schenectady, New York
11. International Filter Company, 50 East Van Buren Street, Chicago, Illinois
12. International Harvester Company, 606 South Michigan Avenue, Chicago, Illinois
13. Ideal Pictures Corporation, 200 Madison Avenue, New York City
14. Keystone View Company, Meadville, Pennsylvania
15. Portland Cement Association, 33 West Grande Avenue, Chicago, Illinois
16. Rothacker Film Corporation, 113-115 West Austin Avenue, Chicago, Illinois
17. Society of Visual Education, 327 LaSalle Street, Chicago, Illinois
18. Spencer Lens Company, 19 Doat Street, Buffalo, New York
19. Stillfilm Inc., 1052 Cahuenga Avenue, Hollywood, California
20. Text Sales Company, 1890 Crenshaw Boulevard, Los Angeles, California
21. United States Department of Agriculture, Washington, D. C.
22. Welch Manufacturing Company, 1515 Sedwick Street, Chicago, Illinois
23. Y. M. C. A., 120 West 41st Street, New York City; 300 West Adams Building, Chicago, Illinois

Unit I. Block 1. Water the Universal Solvent

M. P. "Sewage Disposal"..................(1) 16. S. X. 7.
M. P. "Purifying Water"..................(1) 16. S. X. 7.
M. P. "Work of Underground Water".....(1) 16. R. Y. 8.
F. S. "The Chemistry of Water Treatment"......F. X. 11.

*Prepared by L. Paul Miller, Scranton Central High School.

Unit I. Block 2. Water as a Compound

M. P. "Beyond the Microscope." (1) 16-35. F. X. 10.
M. P. "Chemical Effects of Electricity." (1) 16. S. X. 7.

Unit I. Block 4. Oxygen

M. P. "Magic Flame"................(4) 16-35. F. X. 9.
M. P. "Oxygen Breathing Apparatus".....(1) 35. F. Y. 3.
M. P. "Oxygen, the Wonder Worker." (2, 4) 35. F. X. 3, 23.

Unit II. Block 4. (A) Solutions; (B) Ionization; (C) Valence

M. P. "Beyond the Microscope".........(1) 16. F. X. 10.
M. P. "Chemical Effects of Electricity"...(1) 16. S. X. 7.

Unit III. Block 3. Metals that Touch Our Everyday Life

(A) Iron—Steel

M. P. "Iron Ore to Pig Iron"............(1) 16. S. X. 7.
M. P. "Pig Iron to Steel".................(1) 16. S. X. 7.
M. P. "Story of Steel—Mining and Metallurgy" ....(2) 16-35. F. X. 3.
M. P. "Story of Heat Treatment of Steel" (2) 16-35. F. X. 3.
F. S. "Iron and Steel"................S. Y. 13, 17, 18, 19.
G. S. "Iron and Steel"......................S. Y. 22, 14.

(B) Copper

M. P. "Chemical Effects of Electricity"....(1) 16. S. X. 7.
M. P. "Mining and Smelting of Copper"......(1) 16. Y. 7.
F. S. "Story of Copper"........................S. Y. 13.

(C) Lead

M. P. "Lead" ....(1) 16. S. X. 7.
M. P. "Story of Lead Smelting"..........(2) 35. F. X. 3.
M. P. "Monel Metal"................(2) 16-35. F. Z. 16.

(D) Zinc

M. P. "Story of Zinc Mining"..(1) 35. F. Y. Univ. of Wis.

(F) Sodium

M. P. "Common Salt"....................(1) 16. S. X. 7.
M. P. "Pillars of Salt" ....(1) 16. F. X. 10.
F. S. "Story of Salt" ....S. Y. 13. 18.
G. S. "Story of Salt" ....S. Y. 22, 14.

(G) Calcium

M. P. "Limestone to Marble"............(1) 16. S. X. 7.
F. S. "Building Stone" ....S. Y. 13.
F. S. "Story of Marble".............S. Y. 13, 17, 18, 19.
F. S. "Lime and Limestone"................S. X. 21, 18.
G. S. "Limestone" ....14.

(H) Aluminum

M. P. "Chemical Effects of Electricity"..(1) 16-35. F. Z. 3.
M. P. "Making Wear-Ever Cooking Utensils" ....(1) 16. 35. F. Z. 23.

(I) Silver

M. P. "Art of the Silver Smith"........(1) 16-35 F. Z. 3.
M. P. "Silver" ....(1) 16. S. X. 7.
M. P. "Silver: Heirlooms of tomorrow"..(3) 16-35. F. Z. 3.

(J) Silicon

M. P. "Jewels of Industry"...........(2) 16-35 F. Y. 16.
M. P. "Concrete Facts"................(2) 16-35 F. Y. 3.
M. P. "Story of Portland Cement"......(1) 16-35 F. Y. 6.
M. P. "Fire-Clay Refractories"........(3) 16-35, F. Y. 3.
M. P. "Manufacture and Use of Fire Brick" ....(1) 16-35 F. Y. 23.
M. P. "Sand and Clay"..................(1) 16 S. Y. 7.
M. P. "Table Wear" ....(1) 16. S. Y. 7.
M. P. "The Potters Wheel" ....(1) 16-35. F. Y. 10.
M. P. "Romance of Glass"............(1) 16-35. F. Y. 1.
M. P. "The Magic Jar" ....(1) 16-35. F. Y. 1.
F. S. "Glass" ....S. Y. 13, 18.
G. S. "Glass".................................S. Y. 14.
G. S. "Manufacture of Portland Cement"...(50) F. Y. 15.

Unit IV. Block 1. The Air and the Atmosphere

M. P. "Liquid Air"..................(1) 16-35. F. X. 10.
M. P. "Refrigeration" ....(1) 16-35. S. Z. 23.
M. P. "Silica Gel" (Refrigeration).....(3) 16-35, S. Z. 23.
F. S. "Ice and Refrigeration"............S. Y. 2, 13, 17.
M. P. "Fertilizing Wheat"............(1) 16-35. F. Y. 4.
M. P. "Producing Profitable Corn in the South" ....(1) 16-35. F. Y. 4.
M. P. "Producing Profitable Cotton"....(2) 16-35. F. Y. 4.

Unit IV. Block 2. Sulfur and Its Common Compounds

M. P. "Story of Sulfur"................(2) 16-35 F. X. 6.

Unit IV. Block 3. The Halogen Elements and Fluorine

M. P. "Trip through Filmland"........(2) 16-35 F. X. 6.

Unit IV. Block 4. Phosphorus and Its Compounds

M. P. "Fire Making" ....(1) 16. S. Y. 7.

Unit V. Block 1. Carbon, a Constituent of all Life Compounds—Foods

M. P. "Beet and Cane Sugar" ....(1) 16. S. Y. 7.
M. P. "Cuba, the Island of Sugar"......(2) 16-35 F. Z. 10.
M. P. "Cotton Growing" ....(1) 16. S. X. 7.
M. P. "From Flax to Linens"............(1) 16. S. X. 7.
M. P. "Romance of Rayon"..............(2) 35. F. X. 23.
G. S. "Sets on Farms and Gardens"............F. Y. 12.

Unit V. Block 2. Fuels

M. P. "Carbon Monoxide" ....(1) 16-35, F. X. 3.
M. P. "The Wonders of Anthracite"....(2) 16-35. F. Y. 6.
M. P. "Anthracite Coal" ....(1) 16-35. F. Y. 10.
M. P. "Anthracite Coal" ....(1) 16. S. Y. 7.
M. P. "Bituminous Coal" ....(1) 16-35. F. Y. 10.
M. P. "Bituminous Coal" ....(1) 16. S. Y. 7.
M. P. "Fertilizer from Coal" ....(3) 16-35 F. Y. 16.
M. P. "Saving Coal at Home"..........(1) 16-35 F. Y. 3.
G. S. "Equipment for Burning Coal"...........(50) F. Z.
F. S. "Story of Coal" ....S. Y. 13, 16, 18, 19.
F. S. "Chemistry of Coal" and "Anthracite Mining" ....F. Y. 3.
G. S. "Coal" ....S. Y. 14, 22.
M. P. "Producing Crude Oil".............(1) 16. S. X. 7.
M. P. "Refining Crude Oil" ....(1) 16. S. X. 7.
M. P. "Through Oil Fields of Mexico"..(3) 16-35. F. Z. 3.
M. P. "Refining the Crude" ....(4) 16-35, F. X. 3.
F. S. "Petroleum and Gas".........S. Y. 2, 13, 17, 18, 19.
G. S. "Petroleum" ....S. Y. 14, 22.

Unit V. Block 3. Organic Acids, Bases, and Salts

M. P. "The Chemical Ethyl Alcohol"...(2) 16-35. F. X. 6.
M. P. "Soap" ....(1) 16. S. X. 7.

(1) This is only a partial list of the slides and M. P. material available. Teachers should plan to make a catalog of available materials, (a) which are now available, but are not included above, and (b) which may be available in the future. Obviously, no final list of aids can possibly be drawn up. Lists of visual materials are like continuous motion pictures, not like finished textbooks.

(2) In front of each block above, approximate date may be entered when that topic will be studied in any particular chemistry course. The teacher handling the course may then be guided in advance of free loan and rental materials, most of which must be booked some time ahead.

(3) Want lists may be made up, listing materials which are to be included in annual budgets and equipment orders.

(4) Topics may be selected, for the teaching of which few visual aids are now available, as indicated by few references above. (a) Commercial production of new materials for these topics may be encouraged. (b) Materials may be homemade for these particular topics.

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